

Draft Final Report: Task 1

Identification of *Chemicals of Interest* Related to the Reuse of Produced Waters
for Agricultural Irrigation of Edible Crops

Presented to the California Regional Water Quality Control Board, Central Valley Region

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LIST OF ABBREVIATIONS

ATSDR – Agency for Toxic Substances and Disease Registry

BMD – Benchmark Dose

CalEPA – California Environmental Protection Agency

CS₂ – Carbon disulfide

CASRN – Chemical Abstract Registration Number

CEBS – Chemical Effects in Biological Systems

CICAD – Concise International Chemical Assessment Document

CVRWQCB – Central Valley Regional Water Quality Control Board

d – day

DART – Developmental and Reproductive Toxicology Database

ECHA – European Chemicals Agency

EPA – US Environmental Protection Agency

FDA – Food and Drug Administration

GRAS – Generally Recognized as Safe

GSI – GSI Environmental

HBSL – Human Based Screening Levels

HEAST – Health Effects Assessment Summary Table

HHBP – Human Health Benchmarks for Pesticides

HSDB – Hazardous Substances Data Bank

IARC – International Agency for Research on Cancer

IPCS-INCHEM – International Programme on Chemical Safety Chemical Safety Information from Intergovernmental Organizations

IRIS – Integrated Risk Information System

ITER – International Toxicity Estimates for Risk

kg – kilogram

L – Liter

LOAEL – Lowest Observed Adverse Effect Level

MADL – Maximum Allowable Daily Dose

MCL – Maximum Contaminant Level

mg – Milligram

MOU – Memorandum of Understanding

MRL – Minimal Risk Level

NAWQA – National Water-Quality Assessment

NIEHS – National Institutes of Environmental Health

NIH – National Institutes of Health

NOAEL – No Observed Adverse Effect Level

NOEL – No Observed Effect Level

NORM – Naturally Occurring Radioactive Materials

NSRL – No Significant Risk Level

OECD – Organisation for Economic Co-operation and Development

OEHHA – Office of Environmental Health Hazard Assessment

pCi – picoCurie

PET – Polyethylene terephthalate

ppm – parts per million

PPRTV – Provisional Peer-Reviewed Toxicity Values

RCRA – Resource Conservation and Recovery Act

REACH – Registration, Evaluation, Authorization and Restriction of Chemicals

RfD – Reference dose

TOXNET – Toxicology Data Network

USGS – United States Geological Survey

WHO – World Health Organization

EXECUTIVE SUMMARY

This report describes work completed under Task 1 of the “Memorandum of Understanding Between the Central Valley Regional Water Quality Control Board and Permit Holders Governing the Solicitation, Management and Review of Academic, Technical and/or Scientific Studies Related to the Irrigation of Crops with Oil Field Produced Water”. The primary objective of Task 1 is to prepare a prioritized list of chemicals that may be present in produced water and that would be of interest for further study as part of an evaluation of the beneficial use of produced water for irrigation of food crops. The chemicals considered for this initial prioritization include those known from reliable published sources to be naturally occurring substances in produced water. The list also includes chemical additives reported to the Central Valley Regional Water Quality Control Board (CVRWQCB) as being used in various stages of oil and gas production in the San Joaquin Valley. As a result of this use, the additives may be present in produced water. Chemicals are on the list because they may be present in produced water used for irrigation and not necessarily because they are expected to be found in crops irrigated with produced water.

As part of Task 1, we have characterized and prioritized the initial list of 385 chemicals for further evaluation as chemicals that may pose health risks if present in irrigation water. The primary focus of the prioritization has been based on chronic toxicity to humans. The emphasis on chronic toxicity was intended to maximize the likelihood that the most toxic chemicals are not overlooked.

The 385 chemicals initially identified for evaluation under this task included chemicals known to occur naturally in produced water and chemicals reported to the CVRWQCB as being in use as part of oil and gas production in the Central Valley, as of October 22, 2018. As part of the evaluation completed as part of this task, 134 chemicals were eliminated from further evaluation because the chemical-specific toxicity was sufficiently low that no adverse health effects would be expected. For example, some chemicals were on the Food and Drug Administration’s list of food additives that are Generally Recognized as Safe (GRAS) including acetic acid, citric acid, and bicarbonate, for example. Other additives were eliminated from further consideration because they are virtually nontoxic including almond shells, wood dust, xanthan gum, for example; or because they were not expected to cause adverse health effects at concentrations likely to be present in produced water used for irrigation. For some of the chemicals on the initial list, toxicity information was not available or was not adequate for developing a toxicity factor that could be used in the toxicity ranking table. As result of the lack of chronic oral toxicity data, 77 chemicals could not be evaluated in the toxicity ranking. We will look for environmental fate and transport for these chemicals to see if there are reasons to expect they would not accumulate in irrigated crops.

The remaining list of chemicals after those with low toxicity, or without toxicity information, were removed, were ranked from most toxic to least toxic. The ranking was based on doses not expected to cause adverse noncancer health effects (for noncarcinogens) and doses corresponding to a lifetime incremental cancer risk of one in a hundred thousand (for carcinogens). When toxicity factors (e.g., recommended exposure limits) were available from government or other reliable sources, these values were used for the toxicity ranking. For many chemicals, published toxicity studies were available but had not been used by government agencies to derive toxicity factors. For these chemicals, GSI developed toxicity factors using the same methods as are used by government agencies to derive toxicity factors from published toxicity studies.

The main deliverables of this report are the methods used to evaluate the 385 chemicals that could potentially be present in oil field produced water and five tables that categorize and report our current state of understanding on the toxicology of these chemicals for the most sensitive chronic oral exposure health endpoints. The five tables that were developed using the methods described in this report identify chemicals that: are generally regarded as safe or non-toxic, have insufficient data to identify toxicity, are not chronic oral toxicants, have unclear or unquantifiable toxicity, and those that have quantifiable toxicity.

In the next stage of this project more information on the environmental fate and transport of the chemicals selected for further evaluation will be collected including information on plant uptake as well as biodegradation in water, fugacity of chemicals in water, sorption potential of chemicals, and other mechanisms of physical degradation that could alter the toxicological properties of the identified chemicals or generate degradation products that require evaluation. A literature review of the reuse of produced water in agriculture will also be performed. The results of the toxicity evaluation will be used to focus the collection of information on the fate and transport of chemicals in produced water and the agricultural uses of produced water to prepare an evaluation of the state of knowledge of chemicals important to the beneficial uses of produced water as well as a discussion of the key information gaps.

INTRODUCTION

GSI Environmental (GSI) was retained by a group of companies supplying produced water and entities using that produced water for irrigation of crops for human consumption. This group entered into a Memorandum of Understanding (MOU) with the California Regional Water Quality Control Board, Central Valley Region (Central Valley Water Board)¹. The MOU stipulates that the suppliers and users fund technical work to support the scientific review of using produced water in irrigated agriculture. The MOU also mandates that the Central Valley Water Board controls the technical work performed by GSI. Details regarding the scope of work are outlined on the Central Valley Water Board website². Generally, three main tasks were outlined:

1. Selection of “Chemicals of Interest”, from a list of known chemical additives and naturally occurring chemicals in produced water, for further evaluation
2. Literature review focusing on the “Chemicals of Interest” in the context of produced water reuse in agriculture irrigation and other potential sources of these chemicals in the agricultural water supply
3. Sampling and chemical analysis of crops irrigated with produced water in the Central Valley

This report describes the selection criteria, methods, data sources and results that have been used to-date to identify the “Chemicals of Interest” (Task 1). In the Scope of Work document, it was proposed that the following 13 factors could be considered in the selection of the chemicals of interest, including:

- Oral toxicity information/data (with priority given to chronic mammalian toxicity data)
- Dermal toxicity information/data
- Carcinogenicity information/data
- Teratogenicity information/data
- Environmental persistence/degradation information/data, including soil half-life
- Degradation byproducts of the chemicals and their associated toxicities, carcinogenicity, teratogenicity, endocrine disrupting potential, etc.
- Plant uptake information/data
- Amounts and frequency of use in oil fields
- Chemicals that are persistent, bioaccumulative, and toxic, as defined by the US Environmental Protection Agency (EPA) and other government or scientific organizations
- Chemicals detected in any water quality analyses of irrigation water with maximum measured irrigation water concentrations above available risk-based water screening levels (for example, EPA drinking water screening levels or California Public Health Goals)
- Ambient, background concentrations in air and water that can result from agricultural practices and human activities unrelated to produced water reuse
- Whether the chemical is naturally occurring in the environment

¹ https://www.waterboards.ca.gov/centralvalley/water_issues/oil_fields/food_safety/2017_0627_offs_mou.pdf

² https://www.waterboards.ca.gov/centralvalley/water_issues/oil_fields/food_safety/meetings/2018_0725_offs_mtg_so_ws.pdf

- Other sources of the chemical in the environment and the specificity of the chemical to application of produced water for irrigation

An initial review of these 13 factors resulted in GSI scientists focusing on a systematic review of the available toxicological data and respective literature focused on the toxicological properties of the chemicals as the primary consideration in the evaluation of the Chemicals of Interest. Details of the approach employed for the toxicological evaluation are presented below. This is separate from the literature review outlined as Task 2 in the SOW. While Task 1 is focused on identifying a list of chemicals of interest that could potentially pose a hazard in the context of produced water used for irrigation, Task 2 is a more rigorous review of the available literature on produced water reuse in the context of agricultural irrigation in the Central Valley of California. The review will provide a comprehensive summary of the state of knowledge for the chemicals of interest identified in Task 1, which potentially present in blended produced water used for irrigation.

Work continues on understanding how “Fate and Transport” processes may affect the ultimate presence of these chemicals in food crops irrigated with produced water. GSI is currently reviewing information on hydrolysis, biodegradation, fugacity, and photolysis for each chemical, where available. This evaluation will assist in focusing attention on toxic chemicals that also have the greatest availability for being taken up into food crops when delivered through irrigation waters containing produced water.

IDENTIFYING THE LIST OF CHEMICALS TO BE EVALUATED

Produced water is the largest waste stream of oil and gas extraction. In petroleum reservoirs with low levels of petroleum, large quantities of water are extracted along with a small fraction of crude oil and natural gas. Oil and gas are separated from the water, and the water remains as a waste product. The water can be pumped back into an injection well, treated and discharged, and/or allowed to evaporate. In the context of reuse of produced water for agricultural irrigation, an accounting of the chemical composition is necessary to evaluate the potential risks to human health. Both naturally occurring and additive chemicals may be present in produced water.

Chemicals Thought to Be Naturally Occurring

A number of studies have attempted to characterize the naturally occurring substances in produced water. These studies suggest there is wide variation in the composition of produced water, which can depend on underlying geology, age of the formation, and extraction techniques employed. GSI reviewed a number of peer reviewed journal articles, government documents, and other published materials to identify a list of compounds that have been previously found in produced water and that are seemingly unrelated to the chemical additives. However, the possibility exists that some chemicals are the result of chemical reactions between the mixture of naturally occurring chemicals with chemical additives or among the chemical additives alone. During the review of the literature, GSI identified 45 organic compounds and 45 inorganic compounds likely to be found in produced water, outside of those directly added. As part of the naturally occurring compounds, GSI identified radioactive nuclides as potential constituents of produced water, discussed further below. See Appendix A for the list of chemicals found in produced water that are likely to be naturally occurring.

Additives

The list of oil field additives is provided by the producers and has been published on the Central Valley Water Board website. The list has undergone a number of updates over the past year, and the most recently published list (June 28, 2018) included 362 entries. On October 22, 2018, the Water Board sent GSI an additional 15 compounds for a total of 377 declared entries on the list. The list of chemicals reviewed in this report only include those that were declared by the oil and gas producers prior to October 22, 2018; or they were identified as being naturally occurring. It is possible that other chemicals could be declared in the future. Newly identified chemicals would ostensibly require evaluations similar to that described in this report.

After reviewing the list of chemicals, a number were found to be duplicates due to differences in naming convention or the existence of multiple chemical abstract registration numbers (CASRN). Examples of multiple names for a single chemical are: [d-limonene, citrus terpenes] and [ethoxylated alcohol C11-C14, "alcohol, C11-C14, ethoxylates"]. After removing instances of duplicates, there were a total of 312 unique chemical additives reported by producers within the area under the jurisdiction of the Central Valley Water Board. See Appendix B for the list of petroleum extraction related chemical additives, as evaluated in this report.

Radioactive Materials

Naturally occurring radioactive materials are known to exist in produced water (Zielinski and Otton, 1999). They are incorporated in the petroleum deposit materials due to the dissolution of surrounding minerals over a long period of time. Zielinski and Otton (1999) identified radium (Ra) and uranium (U) as two naturally occurring elements that are found in produced water. Radium is typically found in produced water as only two of 33 known isotopes, Ra-226 and Ra-228. Radium produces both alpha and gamma radiation. The EPA has established a Maximum Contaminant Level (MCL) of 5 picoCuries per liter (pCi/L) for any combination of radium-226 and radium-228 in drinking water. EPA has also established an MCL of 15 pCi/L for alpha particle activity, excluding radon and uranium, in drinking water. A study by Otto (1989) suggests that oil fields in California have low levels of radioactive materials that are at background levels and don't appear to pose additional health risk to humans.

Uranium has toxicity separate from its radioactivity, and this facet of its toxicity is addressed in Table 7. In addition, two radionuclides were reported as additives used by the oil and gas industry during production; these were krypton 85 (Kr-85) and xenon 133 (Xe-133). The additive radionuclides emit beta radiation, and a small amount of gamma radiation in the case of Kr-85. A more comprehensive review of these radioactive elements, their decay products and half-life in the context of water quality measurements taken of the produced water will follow in the literature review, Task 2.

PROCESS FOR EVALUATING THE LIST OF CHEMICALS

In the work presented here, GSI conducted the evaluation of produced water related chemicals by following the six steps below:

1. Identify published chronic toxicity values for the chemicals on the list, where available;
2. From the list of chemicals remaining after (1), a sub-list was generated that represents the comparison between the list of produced water chemicals and the list of 'Generally Recognized as Safe (GRAS)' by the Food and Drug Administration (FDA). This GRAS list

of chemicals has limited to no known chronic toxicity at low exposure levels. Added to this sub-list are other known food additives, supplements, inert compounds and compounds that break down into one of the previously identified chemicals in this step;

3. From the remaining chemicals—after (1) and (2)—research the available peer reviewed literature, government/industry reports, and relevant databases to identify data that characterizes the toxic potential of the remaining chemicals as it relates to chronic oral exposures;
4. From the research activities under (3), identify the sub-list of chemicals for which there are no relevant data characterizing toxic potential related to chronic oral exposures;
5. From the remaining chemicals—after (1), (2), (3), and (4)—create three sub-lists that represent: chemicals with unclear/unquantifiable chronic toxicity, chemicals with no apparent chronic toxicity, and chemicals with quantifiable chronic toxicity;
6. For chemicals without published toxicity values, GSI developed toxicity values based on the scientific literature, where practicable.

During Step 5 of this process, an additional sub-list was developed, representing those chemicals with inconclusive data regarding chronic oral toxicity.

Following this procedure, GSI was able to evaluate and categorize the list of identified chemicals associated with oil and gas production; Figure 1 gives an overview of this work. Of the 385 chemicals on the list, which include both naturally occurring and additive chemicals, GSI identified published toxicity values for 122 of the chemicals. For the remaining 262 chemicals, GSI was able to identify 21 chemicals categorized by the FDA as GRAS by reviewing their published list (FDA, SCOGS). By reviewing the available literature and assessing the toxicity and physical properties of the chemicals, an additional 49 chemicals were included with the list of GRAS chemicals based on their known presence in food or other characteristics related to a lack of overt toxicity; they are essentially non-toxic. Table 3 reports 62 chemicals for which GSI was unable to identify sufficient literature or data to evaluate their relevant chronic oral toxicity; these require further evaluation. Among the remaining chemicals where relevant toxicologic data and literature were available, 64 chemicals did not show evidence of chronic toxicity. There were 11 chemicals that did not have sufficient information to derive conclusions as to their toxicity. Reasons for their inconclusive toxicity are discussed further below; they are listed in Table 5. For the remaining 51 chemicals, GSI developed toxicity values that could be used as part of the process of identifying the chemicals of interest. The set of 173 chemicals with toxicity values, which include 122 with published toxicity values and 43 with derived toxicity values, are reported in section *Chemicals with Quantified Chronic Oral Toxicity Values*. A group of five radionuclides were identified; these comprise both naturally occurring and additive materials.

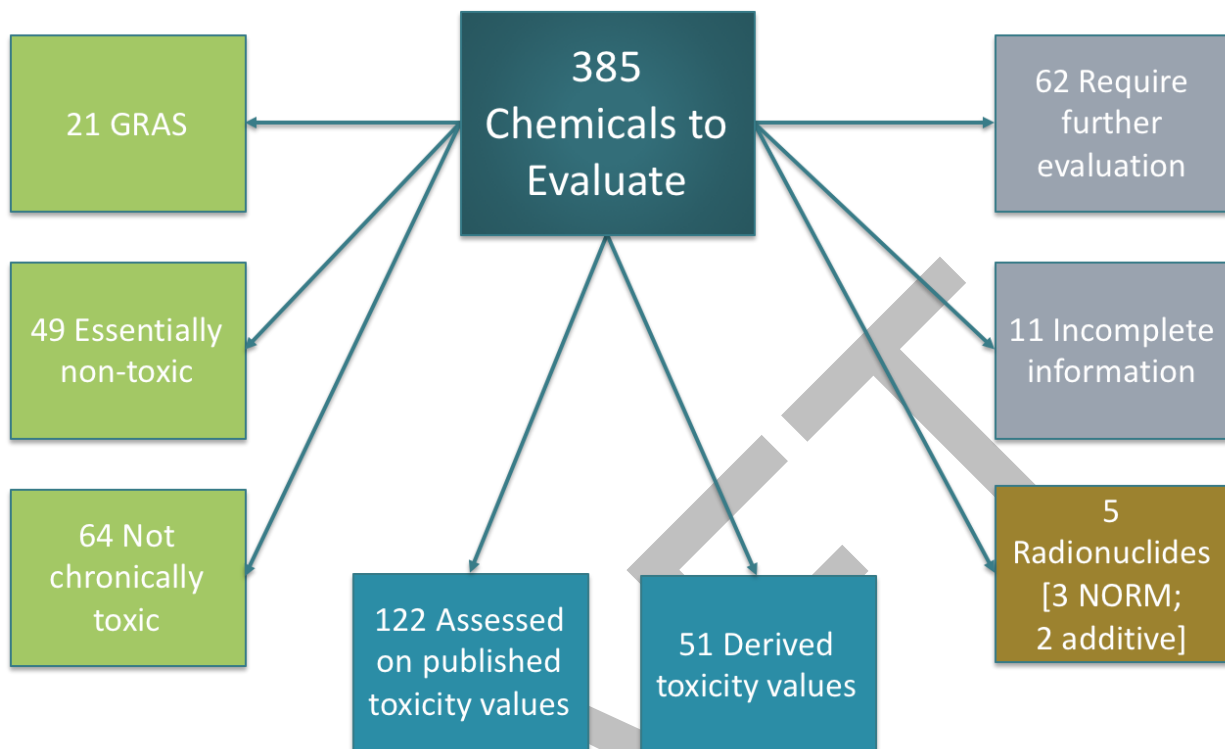


Figure 1: Breakdown of chemical group assignments based on toxicity evaluation

PUBLISHED DATA USED TO EVALUATE TOXICITY

Toxicity in the evaluation of produced water was focused on chronic exposures through the oral route of exposure only. The oral route is the most important route in assessing risks from chemical exposures related to edible crops. The first step was the review of the published government agency data; these sources are described below. Toxicity values were standardized to represent a dose quantified in milligrams per kilogram body mass per day (mg/kg/d). Toxicity levels related to non-cancer outcomes are typically reported in mg/kg/d; however, toxicity values related to cancer outcomes are reported differently.

In the case of cancer outcomes, published toxicity values come in the form of cancer potency; these are typically called a slope factor or unit risk. Slope factors and unit risks represent the increase in cancer risk associated with a lifetime exposure of some incremental unit of exposure. For this assessment, slope factors associated with oral exposure were used to estimate risk specific doses. This risk specific dose is a constant lifetime average exposure level [mg/kg/d] associated with a predefined increase in cancer risk. For this assessment, the predefined excess cancer risk of 1 in 100,000 was used to calculate the standardized toxicity values. This value will act as a reference level and allow for comparisons with non-cancer toxicity values associated with the other naturally occurring and additive chemicals reviewed here.

To put the 1 in 100,000 lifetime risk level in context, the lifetime risk for males in the United States of developing cancer is approximately 40%; for women it is approximately 38% (ACS, 2018). A 1 in 100,000 increase risk of cancer, when compared to the average risk of cancer, is only about

a 0.0025% increase in the average cancer risk. This level is also the threshold level of risk which, if exceeded, requires a warning under The Safe Drinking Water and Toxic Enforcement Act of 1986 (also known as Proposition 65 in California). A 1 in 100,000 increase is a minimal increase in cancer risk beyond risks already experienced by the general population. These standardized toxicity values—both cancer and non-cancer values—were screened for the most sensitive value, i.e., that value which indicated the highest toxicity. The list below identifies the source of the toxicity values used in this evaluation.

- a. EPA Integrated Risk Information System (IRIS) Reference Dose (RfD)
- b. EPA IRIS Oral Slope Factor for Cancer
- c. EPA Provisional Peer-Reviewed Toxicity Values (PPRTV) Oral RfD
- d. EPA Human Health Benchmarks for Pesticides (HHBP)
- e. PPRTV Oral Slope Factor
- f. Agency for Toxic Substances and Disease Registry (ATSDR) Minimal Risk Level (MRL) Oral Chronic Exposure
- g. California Office of Environmental Health Hazard Assessment (OEHHA) Oral Slope Factor
- h. OEHHA Child Specific RfD
- i. OEHHA Cancer No Significant Risk Level (NSRL) Oral Exposure
- j. OEHHA Reproductive/Developmental Maximum Allowable Daily Dose (MADL) Oral Exposure
- k. United States Geological Survey (USGS) Noncancer Human Based Screening Levels (HBSL)
- l. USGS Cancer HBSL
- m. Human Health Toxicity Values in Superfund Risk Assessments Health Effects Assessment Summary Table (HEAST) Oral Slope Factor
- n. HEAST Chronic Oral RfD
- o. HEAST Oral Exposure NOAEL
- p. Other Toxicity Values Derived to Protect Health

United States Environmental Protection Agency Integrated Risk Information System

The United States Environmental Protection Agency (EPA) Integrated Risk Information System (IRIS) is a program within the EPA that characterizes health hazards associated with chemicals in the environment. IRIS published toxicologic assessment values that can be used in identifying risks associated with levels of exposure. Two of the toxicity values published in the IRIS database, oral chronic RfD and oral cancer slope factor, were used as potential criteria in the evaluation of the list of identified chemicals.

The oral RfD is an estimate of the chronic upper daily oral dose that is unlikely to cause an appreciable increase in risk to health during a lifetime. It can be derived from a no observed adverse effect level (NOAEL), lowest observed adverse effect level (LOAEL), or benchmark dose (BMD). To these observed [NOAEL and LOAEL] or derived [BMD] effect levels, it is convention in developing RfDs that uncertainty factors are applied to derive a health protective toxicity value;

this is discussed in more detail later. The RfD is used to characterize risks associated with exposures related to non-cancer outcomes.

The US EPA, through IRIS, also reports oral slope factors for cancer outcomes (discussed above).

Superfund Program's Provisional Peer Review Toxicity Values

Within the Superfund Program, through the EPA, toxicological assessments of certain chemicals were made to support health hazard identification and risk assessments associated with the Superfund Program. Provisional Peer Reviewed Toxicity Values (PPRTV) are derived from review of the scientific literature; Agency methodologies, practices, and guidance are then employed for the development of toxicity values (US EPA, PPRTV). PPRTVs are available for provisional oral RfDs, provisional inhalation reference concentrations, provisional oral slope factors, and provisional inhalation unit risks. In evaluating the identified list of oil and gas extraction chemicals, provisional oral RfDs and provisional oral slope factors were used from the PPRTV database.

Agency for Toxic Substances and Disease Registry Minimal Risk Levels

The Agency for Toxic Substances and Disease Registry (ATSDR) develops Minimal Risk Levels (MRL) for hazardous substances under its responsibility to characterize chemicals likely to be found at Superfund sites. These evaluations are done in coordination with the EPA using similar methods to those used by the EPA in developing RfDs (ATSDR, 2018). That is, they may incorporate both human and animal data. Like the EPA IRIS RfD, they build in the assumption that humans are more sensitive to these chemicals than animals. They are derived for multiple exposure time regimes: acute (1-14 days), intermediate ($> 14-364$)³, and chronic (≥ 365 days). It should be noted that MRLs are only defined for non-cancer outcomes and are based on the most sensitive outcome of human relevance. MRLs are not based on serious outcomes, such as irreparable kidney damage or birth defects; because of safety factors that are built into the assigned toxicity value, exposures above the MRL do not represent an implicit risk to health.

Office of Environmental Health Hazard Assessment

The Office of Environmental Health Hazard Assessment (OEHHA) is a department of the California Environmental Protection Agency (CalEPA) whose mission is to protect and enhance public health and the environment by objective scientific evaluation of risks posed by hazardous substances. Not only does OEHHA provide many of the same kinds of support in the derivation of toxicity values as the federal EPA's IRIS, but it also supports The Safe Drinking Water and Toxic Enforcement Act of 1986, otherwise known as Proposition 65. In the context of Proposition 65, OEHHA derives toxicity related dose levels for cancer, reproductive and developmental outcomes. In the evaluation of the identified chemicals related to oil and gas extraction, GSI identified the following toxicity values published by OEHHA: oral child specific RfD, oral slope factors, maximum allowable dose level (MADL) and no significant risk level (NSRL).

United States Geological Survey Human Based Screening Levels

The United States Geological Survey (USGS) Human Based Screening Levels (HBSL) are derived water standards used to supplement US EPA Maximum Contaminant Levels (MCLs) and

³ This time regime is commonly referred to as sub-chronic

Human Health Benchmarks for Pesticides (HHBPs). HBSLs are used to determine whether contaminants found in surface-water or groundwater sources of drinking water are a potential human-health concern. HBSLs were developed by the U.S. Geological Survey (USGS) National Water-Quality Assessment (NAWQA) Project for contaminants without US EPA MCLs or HHBPs. Since HBSLs are published as water concentration values, we have converted the concentrations to represent a child-specific dose level related to a water exposure. When MCLs are derived, the assumption is made that a child of 10 kg ingests 1 liter of water per day. This allows us to estimate the mg/kg-day dose equivalent that can then be compared to the other toxicity values.

Health Effects Assessment Summary Tables for Superfund

Health Effects Assessment Summary Tables (HEASTs) were published databases of human health toxicity values developed for the EPA Superfund and Resource Conservation and Recovery Act (RCRA) hazardous waste programs. Toxicity values published in these databases are provisional; as of 2002 they have been superseded by the PPRTV database. GSI included this database in reviewing toxicity values for the sake of thoroughness.

Other Sources of Toxicological data

GSI used a web search approach to identify relevant literature. In addition to Google Web Search and Google Scholar, we used health and toxicologic specific databases available on the internet; these included PubMed, National Institutes of Environmental Health (NIEHS), Chemical Effects in Biological Systems (CEBS), National Institutes of Health (NIH), Toxicology Data Network (TOXNET), NIH PubChem, World Health Organization (WHO) Concise International Chemical Assessment Document (CICAD), International Programme on Chemical Safety Chemical Safety Information from Intergovernmental Organizations (IPCS-INCHEM), and the database of registration dossiers through the European Chemical Agency's (ECHA) Registration, Evaluation, Authorization and Restriction of Chemicals (REACH) program.

TOXNET is a metasearch database comprised of a number of health-related databases. GSI used it to identify relevant literature by focusing on results from the following databases that it contained: Hazardous Substances Data Bank (HSDB) contains peer-reviewed toxicology data for over 5,000 hazardous chemicals; TOXLINE contains 4 million references to literature on biochemical, pharmacological, physiological, and toxicological effects of drugs and other chemicals; Developmental and Reproductive Toxicology Database (DART) contains references to developmental and reproductive toxicology literature; the Household Products Database, which contains data identifying potential health effects of chemicals in more than 10,000 common household products; Haz-Map, which links jobs and hazardous tasks with occupational diseases and their symptoms and also identifies specific chemicals and hazards associated with them; and International Toxicity Estimates for Risk (ITER), which contains risk information for over 600 chemicals from authoritative groups worldwide.

Through the REACH program in the European Union, companies are required to register their substances in combination with other companies who are registering the same substance. From the registration dossier, GSI was able to identify chemical and physical properties, environmental fate and pathway information, and toxicological information. Most importantly, within the toxicological section, data from difficult-to-find and unpublished reports were made available that identified the presence or absence of relevant health effects associated with repeated dose oral exposures.

DEVELOPING TOXICITY VALUES FOR NON-ASSESSED CHEMICALS

Toxicity values have not been derived for a large number of the chemicals related to oil and gas extraction that are evaluated here. For some of these chemicals, this is because they have low toxicity, but for many of them, there have not been any formal toxicologic assessments. GSI reviewed the available literature to identify which of the chemicals had human or animal toxicologic data related to chronic exposures, and used that data, when applicable, to derive toxicity values that could be integrated into the database of toxicity values gathered from previously published (usually government agency) sources.

Methods to Develop Comparable Toxicity Values for Non-Assessed Chemicals

The toxicity values that GSI developed for this assessment were of the same form as a RfD, i.e., a dose level reported in mg/kg/d that is unlikely to adversely affect health under chronic exposure. The methods that GSI employed in the development of these values were guided by the process employed by the EPA in establishing RfDs (US EPA, 2002). In short, the process can be thought to have four main steps: (1) development and evaluation of a database identifying studies that identify adverse outcomes related to exposures to a specific chemical; (2) identification of the critical effect, defined as “the first adverse effect, or its known precursor, that occurs to the most sensitive species as the dose rate of an agent increases”; (3) identifying the NOAEL or LOAEL associated with the critical effect; and (4) developing the RfD by adjusting the NOAEL or LOAEL based on uncertainty factors specific to the study where the NOAEL or LOAEL were identified.

For nearly all of the chemicals evaluated here, there was insufficient toxicologic literature to develop databases of the scope that is typically used in these kinds of evaluations, i.e., inclusion of tens to hundreds of studies looking at outcomes in multiple species to various biologic systems. These large databases allow the EPA and other agencies to thoroughly evaluate a chemical's toxicity based on the following criteria:

- Have adequate studies been conducted to establish the target organs/endpoints?
- Have the effects been characterized for both sexes and all life stages?
- Are data pertaining to potentially susceptible subpopulations available?
- Are the responses consistent across species? Are the results of the studies biologically plausible?
- Are the route and matrix of exposure relevant to the specific reference value being derived?
- Is the duration of exposure appropriate for the specific reference value being derived?
- Is the animal species and strain appropriate for extrapolation to humans?
- To what degree may the biological endpoints be extrapolated (qualitatively and quantitatively) to humans?
- Are toxicokinetic data available? Are they available for both sexes, for relevant life stages, or for other susceptible subpopulations?
- Is the shape of the dose-response curve consistent with the known toxicokinetics of the test compound?
- Are the metabolism and toxicokinetics in the animal species similar to those of humans?

- Has the dose-response curve been replicated by, or is it consistent with, data from other laboratories and other test species?
- Have the data for all relevant endpoints been adequately modeled by the BMD or other appropriate quantitative analysis to determine the most sensitive endpoint(s)?
- How well is the toxicity characterized? Do the results of the identified studies indicate the possibility of effects on particular systems that have not yet been explored sufficiently, or do they indicate that additional studies may reveal effects not yet characterized?

For many of the chemicals, only a few relevant studies were available. GSI evaluated the toxicological studies of the non-assessed chemicals as best practicable, congruent with the overarching principles of evaluation criteria above. However, due to the limited number of available studies, truncated evaluations of the chemicals were conducted. For inclusion in the evaluation, the studies related to toxicological properties of a chemical needed to satisfy the following:

- Is the outcome physiologically relevant to humans? I.e., do humans have the same physiological structure that the chemical can act on?
- Can the toxicokinetics of the chemical associated with the outcome in animals be plausibly extrapolated to humans? This criterion would only exclude studies if it was positively known that specific metabolic pathways of action did not apply to humans.
- Is the outcome associated with oral exposure in the sub-chronic (90-365 day) to chronic (> 1 year) exposure time period?

In identifying the critical effect, the outcome with the lowest published NOAEL or LOAEL that satisfied the three minimum criteria (above) was chosen to develop a toxicity value. As the final step in the evaluation, based on parameters specific to the identified study, a toxicity value comparable to the EPA RfD is developed by adjusting the NOAEL or LOAEL by a combination of uncertainty factors. In a few cases, GSI conducted a 'read-across assessment' when toxicity data were not available for a specific chemical. Read-across assessments are common practice in chemical risk assessments when data specific to a chemical are not available but are available for structurally or functionally similar chemicals.

For the read-across assessment, toxicity data from similar chemicals with similar functional groups were used as a substitute for the naturally occurring or additive chemical on the list. For example, toxicity data from benzenesulfonic acid C10-16-alkyl derivatives was used in the assessment of the similar alkylarylsulfonate amine salt, which does not have any specific toxicity data available. Alkylarylsulfonate amine salt is benzenesulfonic acid compounded with isopropylamine. Isopropylamine is a known irritant that can cause chemical burns with oral exposure at high concentrations, with no other known systemic effects. In addition, isopropylamine is readily biodegradable in water (ECHA, Isopropylamine), and hence, unlikely to contribute significantly to any overt toxicity of concern here, which is in addition to the benzenesulfonic acid. Read-across assessments of this kind are explicitly identified in Table 7 for chemicals evaluated in this report.

After following the process outlined above to identify a NOAEL or LOAEL for a critical effect, the associated RfD is derived by taking the NOAEL or LOAEL and dividing it by a number of uncertainty factors. In developing the toxicity value comparable to a RfD, up to six uncertainty

factors were used to appropriately scale the NOAEL or LOAEL; these were based on the studies' characteristics and include allometric scaling, other interspecies differences, intraspecies differences, exposure/duration differences, dose/response considerations, and quality of the study. Equation 1 represents the calculation of the RfD. The denominator is a product of a number of potential uncertainty factors, U_i .

$$RfD = \frac{NOAEL \text{ or } LOAEL}{\prod U_i} \quad \text{Eq. 1}$$

The general guidelines from the EPA in developing a RfD are to apply factors of 10 for each of the following: adjusting from animal to human, adjusting for sub-chronic to chronic, adjusting for susceptible populations, and adjusting a LOAEL to NOAEL (US EPA, 2002). Adjustments for dose-response considerations, additional intraspecies differences, and the quality of the study used are typically left to the researcher or research committee to decide. GSI followed these guidelines in adjusting for sub-chronic to chronic study design, susceptible populations, and in adjusting a LOAEL to equivalent NOAEL.

GSI modified the approach, however, when initially adjusting from animals to humans. Given that the primary goal of this work is to identify a priority list of chemicals of interest—and not health protective values—this requires comparison between RfDs derived from studies with different study designs. To accomplish this goal, GSI incorporated species-specific adjustment factors based on relationships between metabolic rates and body size, instead of the standard factor of 10 typically used by the EPA and other agencies. This would better allow for the ultimate ranking of a chemical's toxicity by more equally evaluating relative toxicity for these previously unevaluated chemicals. For example, raw toxicity data derived from baboon studies, which are arguably more similar to humans than many other animals, can be more equally compared to raw data derived from mouse studies. To more equally be able to compare the toxicity values derived from these two different species, species-specific adjustments need to be made.

Instead of using the 10 times factor, as would typically be done by the EPA in developing a health protective RfD, allometric scaling factors were used to account for uncertainty in animal data. Allometric scaling is a way to translate dose related effects observed in one species to another species by adjusting the administered dose based on metabolic differences. These metabolic differences, on average, are proportional to the differences between body surface areas. This is one way of scaling toxicity data between animals and humans and is a recommended method by the FDA for use in pharmacokinetic/toxicologic evaluations. For example, in Phase I clinical trials, where the goal is only to test the drug safety in humans, allometric scaling is part of the process that the FDA suggest industry use to establish the maximum recommended starting dose based on previously collected animal data (FDA, 2005). The FDA publishes allometric scaling values for a range of animals (FDA, 2005), see Table 1.

Occasionally, other interspecies differences—in addition to allometric scaling—need to be applied to account for other uncertainties, such as other metabolic differences (i.e., species-specific metabolic pathway differences) or known differences in gut absorption. For example, if it was known that a species absorbed a chemical at half the rate of a human, an additional factor of two would be applied, given that absorption in an animal would be represented by two times that amount in humans. As a final uncertainty factor, in studies where data quality was not sufficiently

reliable, for example, when few samples were available, an additional uncertainty factor may be applied; this ranged between 5-10.

Given the list of chemicals GSI developed with toxicity values comparable to published values, only non-cancer outcomes were observed in the studies that informed the evaluations.

RESULTS OF THE REVIEW OF CHEMICALS

The following sections report the results of the literature review and toxicological assessment of chemicals related to oil and gas production. Five tables in this section present the results of the evaluation process presented earlier in the section "Process for Evaluating the List of Chemicals." Table 2 reports chemicals that are essentially non-toxic; Table 3 reports chemicals with insufficient data to make any characterization as to chronic toxicity; Table 4 reports chemicals without chronic oral toxicity; Table 5 reports the list of chemicals with incomplete information; and Table 7 reports the combined list of chemicals with published and derived toxicity values.

Chemicals That are Essentially Non-toxic or Generally Regarded as Safe (GRAS)

After identifying chemicals with published values (reported in Table 7), GSI identified 68 chemicals/additives (Table 2) that did not appear to have any conspicuous chronic oral toxicity. The lack of toxicity was based on:

- The FDA Generally Regarded As Safe (GRAS) list
- Known constituents of the human diet
- A common food additive or supplement
- Known to be essentially non-toxic
- Inert
- Upon combination with water, the chemical will become one of the previously mentioned groups

GRAS is a designation given to compounds by the FDA. A list of these compounds can be found at the Food Ingredient and Packaging Inventory (FDA, SCOGS); only those chemicals listed as GRAS in the FDA database are reports as such. Chemicals listed here for reasons other than being on the GRAS list are explicitly stated in Table 2.

12 of the compounds listed in Table 2 merit additional discussion, which follows:

(1) Dimethyl siloxane and silicones, which are used in the biomedical field and in cosmetics as emollients, have been heavily researched and found to be virtually non-toxic to mammals (Moretto et al., 2005).

(2) The same assessment can be applied to polydimethylsiloxane emulsion as for dimethyl siloxane and silicones (Moretto et al., 2005).

(3) Hydroxymethyl cellulose, which is used as a thickening agent, is not absorbed to an appreciable degree and appears unchanged in feces after ingestion (Bingham et al., 2001).

(4) Ethoxylated sorbitan monooleate, otherwise known as polysorbate 80 is used in both the food and cosmetics industry where it is GRAS (Rowe et al., 2006).

(5) Magma fiber, which is a mineral fiber that is soluble in acidic environments, typically contains calcium oxide (CaO), magnesium oxide, and aluminum (III) oxide. Under acidic aqueous environments, this may enrich waters with calcium, magnesium, and aluminum ions. Of the three, there is some concern over increased aluminum concentrations. Toxicity with chronic aluminum exposure is addressed later in the list of chemicals of interest.

(6) Polyethylene terephthalate (PET) oral toxicity is not expected to be high. It is used as a packaging material and health concerns are related to irritation (DAK Americas, 2008). Some concern exists over antimony migration from PET into water due to residual antimony left over from its production (Tukur et al., 2012). Potential antimony exposures are specifically addressed later in the list of chemicals of interest.

(7) Hydrochloric acid is naturally produced in the stomach as a digestive agent (pH 1.5 to 3.0). Its toxicity is related to its corrosivity, which is directly related to its pH level. A 1% by weight aqueous solution of hydrochloric acid has a pH of approximately 2.5. In comparison, lemon juice has a pH that can reach as low as 2. It is unlikely that hydrochloric acid concentrations/pH would reach levels nearing that of lemon juice, as it would make irrigation with those waters impossible. As such, in the context of hydrochloric acid content in waters used for irrigation, levels likely to be observed in those waters are toxicologically irrelevant.

(8) Cellophane is produced by treating cellulose with an alkali and carbon disulfide to create viscose. In its production, toxicity arises due to the carbon disulfide (CS₂) that is used during manufacturing of viscose (Kuo et al., 1997), which is the parent material of cellophane. CS₂, however, is carefully recovered during manufacturing, allowing the cellophane to be used to wrap food stuff. It has been used since the early 1900's to wrap food stuff with no known concerns to health; it is readily biodegradable (Lamot and Voets, 1978). Given its long history of use with no known health concerns, and the innocuous nature of its biodegradation by-products, there is no reason to consider cellophane toxic.

(9) Saponite is a group of clay minerals with some research looking at their toxicities. Saponite is a subtype of smectite. In one study, rats were fed montmorillonite (a different subtype of smectite) with their chow during pregnancy; no effects were observed in the dam or offspring (Wiles et al., 2004). It is expected that there is low toxicity associated with these clays (Zoltan et al., 2005). Smectite clays are used in the production of pelletized animal food (Odom et al., 1984).

(10) The same assessment can be made for the more general group of smectite clays, as for saponite.

(11) Magnesium is a dietary requirement and regularly ingested as a dietary supplement. The tolerable upper limit for supplemental magnesium in a young child is 65 mg and for an adult is 350 mg (IOM, 1997). For a 10 kg child, a more sensitive receptor, the upper tolerable limit is 6.5 mg/kg/day. It is not expected that levels of magnesium in produced water would be very high; it was reported in Guerra et al. (2011) that Mg in produced water was in the range of 1.2 mg/L, which for a 10 kg child, drinking 1 L per day would equate to a dose of 0.12 mg/kg/d.

(12) Ammonium chloride is an acidifying agent used to treat alkalosis and metabolized as ammonia, which doesn't appear to demonstrate chronic toxicity (TOXNET 2015).

Chemicals with Insufficient Data to Identify Toxicity

In reviewing the literature and available databases, there was a subset of compounds where there was no relevant data to make a toxicological assessment (Table 3). In most cases, little information on toxicity was available. When possible, alternative names for the compounds were identified to assist in categorizing the compounds. Efforts were made to use the given and found names to conduct read-across assessments, where toxicity from similar compounds were used as surrogate indicators of potential toxicity. However, in the case of chemicals reported in Table 3, the identification of alternate names revealed that there were functional groups or mixtures of chemicals which made a read-across assessment impracticable.

Chemicals Without Chronic Oral Toxicity

In reviewing the available literature, 62 of the naturally occurring or chemical additives were identified as not exhibiting chronic oral toxicity based on published studies and data. Unlike the chemicals reported in Table 2, which are mostly food additives or similar, those reported here are not approved for food and not inert. Table 4 summarizes GSI's findings for chemicals that have not shown health risks associated with repeated dose oral exposures. In cases where only one study is reported, this can represent the following conditions: only one study is available, the study reports the most sensitive NOAEL, or a study represents the highest exposure level where no effect is observed. The highest exposure level where no effect is observed is called the No Observed Effect Level (NOEL).

Chemicals with Incomplete Chronic Oral Toxicity

During the searches to identify chemicals with chronic toxicity through oral exposure, in the case of 12 database entries, some information on toxicity was available, but there was either insufficient information on chronic oral toxicity to make a determination as to its potential toxicity in humans, or conflicting evidence was available. In a few cases, the definition, i.e., lack of CASRN, made an assessment difficult. Discussions explaining reasons for classification in this group are provided in Table 5. An additional discussion is also presented for aromatic amines, in general, where specific species were not identified in the list of chemical additives.

Aromatic amines are a broad group of chemicals listed as additives by the producers. This lack of specificity made it difficult to evaluate toxicity. Aromatic amines can cause moderate to severe poisoning, with symptoms ranging from headache, dizziness, and ataxia to anemia, cyanosis, and reticulocytosis and cancer (Patnaik, 1992). In general, the most sensitive outcomes related to chronic exposure to aromatic amines appear to be cancer related. For example, the non-cancer RfD published by EPA in the IRIS database for Benzidine is 0.003 mg/kg/d. In contrast, for the same chemical, a dose associated with a 1 in 100,000 increase in cancer is 0.0004 mg/kg/d—a dose that is nearly 10 times smaller. IARC has evaluated a number of aromatic amines as to their carcinogenicity in Monograph 99 (IARC, 2010a). Below, in Table 6, is the list of aromatic amines evaluated in the monograph and the conclusions drawn from their scientists' evaluations as to their carcinogenicity.

Chemicals with Quantified Chronic Oral Toxicity Values

Table 7 identifies the list of chemicals that have been identified to exhibit chronic oral toxicity and were not eliminated for reasons otherwise specified above. The table includes chemicals with both published and derived chronic oral toxicity values. For each chemical listed in Table 7, several pieces of data related to identification, toxicity, and fate and transport are summarized,

including CASRN, chemical name, biodegradability in water, NOAEL/LOAEL from the animal study, the aggregate uncertainty factor used in the derivation of the toxicity factor, the toxicity value we have adopted for purposes of this evaluation, and the Organisation for Economic Co-operation and Development (OECD) biodegradation in water classification. For table entries representing toxicity values from published sources (i.e., RfDs from EPA, MRLs from ATSDR), the NOAEL/LOAEL and uncertainty factor are not reported. Table 7 has been ordered from most-to least-toxic, based on the reported toxicity values. This completes the primary step in the evaluation of the list of chemicals. Resolving issues of environmental fate and transport, as they relate to this list of chemicals, will help to focus the list further.

Biodegradability in water is reported in Table 7 as an interim step in addressing issues of fate and transport. Biodegradability classifications of 'readily,' 'inherently,' and 'poorly' biodegradable are reported. Readily biodegradable is defined as the ability of a product to biodegrade quickly and completely to $\geq 60\%$ in 28 days by OECD 301/ASTM D7373 testing. Inherently biodegradable is defined as $> 20\%$ but $< 60\%$ biodegradation in 28 days by naturally occurring organisms under OECD 301B testing conditions. Poorly biodegradable compounds will degrade less than 20% in 28 days under the same testing conditions and timeframe. Ongoing work aims to translate experimental fate and transport data to address potential hazards related to use of produced water for irrigation purposes; these data include biodegradation data for water, fugacity of chemicals in water, sorption potential of chemicals, and other mechanisms of physical degradation. Integration of fate and transport parameters was originally itemized as a goal of Task 1. Discussions with the Water Board and Scientific Advisor have moved the more complete exploration of how fate and transport will affect the hazard profile of these chemicals of interest to Task 2.

REFERENCES

- ACGIH. 2012. American Conference of Governmental Industrial Hygienists. Documentation of Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices for 2012. Cincinnati, OH. 2012.
- ACS. 2018. Cancer Basics: Lifetime Risk of Developing or Dying From Cancer. American Cancer Society. [<https://www.cancer.org/cancer/cancer-basics/lifetime-probability-of-developing-or-dying-from-cancer.html>]. Accessed 01/13/2019.
- ACT. 1992. Acute Toxicity Data. Journal of the American College of Toxicology, Part B. Vol. 1, Pg. 742, 1992.
- Albaho, M.S., 2006. Cross-sectional area of the root medium affects water uptake of tomato in a closed system.
- Andrade, V.T., Andrade, B.G., Costa, B.R.S., Pereira, O.A. and Dezotti, M., 2010. Toxicity assessment of oil field produced water treated by evaporative processes to produce water to irrigation. Water Science and Technology, 62(3), pp.693-700.
- Anlezark, G., Horton, R.W., Meldrum, B.S., Christina, M. and Sawaya, B., 1976. Anticonvulsant action of ethanolamine-O-sulphate and di-n-propylacetate and the metabolism of γ -aminobutyric acid (GABA) in mice with audiogenic seizures. Biochemical pharmacology, 25(4), pp.413-417.
- Astill, B.D., Deckardt, K., Gembardt, C., Gingell, R., Guest, D., Hodgson, J.R., Mellert, W., Murphy, S.R. and Tyler, T.R., 1996. Prechronic toxicity studies on 2-ethylhexanol in F334 rats and B6C3F1 mice. Toxicological Sciences, 29(1), pp.31-39.
- ATSDR. 1995. Toxicological profile for Polycyclic Aromatic Hydrocarbons (PAHs). US Department of Health and Human Services, Agency for Toxic Substances and Disease Registry.
- ATSDR. 2006. Toxicological profile for hydrogen sulfide. US Department of Health and Human Services, Agency for Toxic Substances and Disease Registry.
- ATSDR. 2007. Toxicological profile for Barium. US Department of Health and Human Services, Agency for Toxic Substances and Disease Registry.
- ATSDR. 2017. Toxicological profile for Silica (Draft for public comment). US Department of Health and Human Services, Agency for Toxic Substances and Disease Registry.
- ATSDR, 2018. Minimal Risk Levels (MRLs) – For Professionals. US Department of Health and Human Services, Agency for Toxic Substances and Disease Registry. Page last updated: June 21, 2018. [<https://www.atsdr.cdc.gov/mrls/index.asp>]. Accessed 2/9/2019.
- Azetsu-Scott, K., Yeats, P., Wohlgelassen, G., Dalziel, J., Niven, S. and Lee, K., 2007. Precipitation of heavy metals in produced water: Influence on contaminant transport and toxicity. Marine environmental research, 63(2), pp.146-167.

- Ballantyne, B. and Snellings, W.M., 2007. Triethylene glycol HO (CH₂CH₂O) ₃H. *Journal of Applied Toxicology: An International Journal*, 27(3), pp.291-299.
- Benko, K.L. and Drewes, J.E., 2008. Produced water in the Western United States: geographical distribution, occurrence, and composition. *Environmental Engineering Science*, 25(2), pp.239-246.
- Bingham, E.; Cohrssen, B.; Powell, C.H.; *Patty's Toxicology Volumes 1-9 5th ed.* John Wiley & Sons. New York, N.Y. 2001., p. 944
- Brendehaug, J., Johnsen, S., Bryne, K.H., Gjose, A.L., Eide, T.H. and Aamot, E., 1992. Toxicity testing and chemical characterization of produced water—a preliminary study. In *Produced water* (pp. 245-256). Springer, Boston, MA.
- Browning, E. and Snyder, R., 1987. *Ethel Browning's toxicity and metabolism of industrial solvents: Hydrocarbons (Vol. 1)*. Elsevier Science Limited.
- BUA (1997) [Glyoxal.] German Chemical Society (GDCh) Advisory Committee on Existing Chemicals of Environmental Relevance (BUA). Stuttgart, S. Hirzel, Wissenschaftliche Verlagsgesellschaft, pp. 1-64 (BUA Report 187) (in German).
- Bylka, W., Znajdek-Awiżeń, P., Studzińska-Sroka, E. and Brzezińska, M., 2013. *Centella asiatica* in cosmetology. *Advances in Dermatology and Allergology/Postępy Dermatologii i Alergologii*, 30(1), p.46.
- Chudzik, M., Korzonek-Szlacheta, I. and Król, W., 2015. Triterpenes as potentially cytotoxic compounds. *Molecules*, 20(1), pp.1610-1625.
- Coutinho, E.M., 2002. Gossypol: a contraceptive for men. *Contraception*, 65(4), pp.259-263.
- DAK Americas, LLC; Material Safety Data No. DK0003 (Polyethylene terephthalate). April 230, 2008. Available from, as of March 17, 2009:
- DeMerlis, C.C. and Schoneker, D.R., 2003. Review of the oral toxicity of polyvinyl alcohol (PVA). *Food and chemical Toxicology*, 41(3), pp.319-326. Du Pont (E. I. du Pont de Nemours and Company). 1992. Unpublished report HLR 229-92 as reported in OECD/SIDS (1996).
- ECHA. 1,2-benzisothiazol-3(2H)-one. REACH Registration Dossier. [<https://echa.europa.eu/registration-dossier/-/registered-dossier/22961>].
- ECHA. 1-Hexadecene: REACH Registration Dossier. [<https://echa.europa.eu/registration-dossier/-/registered-dossier/14122/1>].
- ECHA. 2-Amino-2-methylpropano. REACH Registration Dossier. Last modified 16-Nov-2018. [<https://echa.europa.eu/registration-dossier/-/registered-dossier/11767/7/1>].
- ECHA. 2-hydroxyethyl)ammonium mercaptoacetate. REACH Registration Dossier. [<https://echa.europa.eu/registration-dossier/-/registered-dossier/10836>].

- ECHA. (2-methoxymethylethoxy)propanol. REACH Registration Dossier. [<https://echa.europa.eu/registration-dossier/-/registered-dossier/14751/7/1>].
- ECHA. 2-methyl-2H-isothiazol-3-one. REACH Registration Dossier. [<https://echa.europa.eu/registration-dossier/-/registered-dossier/23868/7/1>].
- ECHA. 2-methylbut-3-yn-2-ol. REACH Registration Dossier. [<https://echa.europa.eu/registration-dossier/-/registered-dossier/12665/7/6/1>].
- ECHA. 2-Propenoic acid, homopolymer. REACH Registration Dossier. [<https://echa.europa.eu/registration-dossier/-/registered-dossier/22071>].
- ECHA. 2,2',2''-(hexahydro-1,3,5-triazine-1,3,5-triyl)triethanol. REACH Registration Dossier. [<https://echa.europa.eu/registration-dossier/-/registered-dossier/15014>].
- ECHA. 4-Nonylphenol, branched, ethoxylated. REACH Registration Dossier. [<https://echa.europa.eu/registration-dossier/-/registered-dossier/19064/7/6/1>].
- ECHA. Acetaldehyde. REACH Registration Dossier. [<https://echa.europa.eu/registration-dossier/-/registered-dossier/10673/1>].
- ECHA. Alkanes, C12-14-iso-. REACH Registration Dossier. [<https://echa.europa.eu/registration-dossier/-/registered-dossier/11519/1>].
- ECHA. Amines, C12-16-alkyldimethyl. REACH Registration Dossier. [<https://echa.europa.eu/registration-dossier/-/registered-dossier/5705/7/1>].
- ECHA. Ammonium hydrogensulphite. REACH Registration Dossier. [<https://echa.europa.eu/registration-dossier/-/registered-dossier/14587/7/1>].
- ECHA. Ammonium sulphate. REACH Registration Dossier. [<https://echa.europa.eu/registration-dossier/-/registered-dossier/15571/7/1>].
- ECHA. Ammonium thiosulphate. REACH Registration Dossier. [<https://echa.europa.eu/registration-dossier/-/registered-dossier/14499/7/1>].
- ECHA. Benzene, mono-C11-C13-branched alkyl derivatives. REACH Registration Dossier. [<https://echa.europa.eu/registration-dossier/-/registered-dossier/16161/7/1>].
- ECHA. Cyclohexanol. REACH Registration Dossier. [<https://echa.europa.eu/registration-dossier/-/registered-dossier/15181>].
- ECHA. Distillates (petroleum), hydrotreated heavy paraffinic. REACH Registration Dossier. [<https://echa.europa.eu/registration-dossier/-/registered-dossier/15636/7/6/2>].
- ECHA. Distillates (petroleum), hydrotreated light naphthenic. REACH Registration Dossier. [<https://echa.europa.eu/registration-dossier/-/registered-dossier/15734>].
- ECHA. Distillates (petroleum), hydrotreated light paraffinic. REACH Registration Dossier. [<https://echa.europa.eu/registration-dossier/-/registered-dossier/15621/7/1>].

- ECHA. Distillates (petroleum), hydrotreated light. REACH Registration Dossier. [<https://echa.europa.eu/registration-dossier/-/registered-dossier/15375/7/1>].
- ECHA. Docusate sodium. REACH Registration Dossier. [<https://echa.europa.eu/registration-dossier/-/registered-dossier/16066/7/1>].
- ECHA. Dodecane. REACH Registration Dossier. [<https://echa.europa.eu/registration-dossier/-/registered-dossier/13433/1>].
- ECHA. Dodecylbenzenesulphonic acid. REACH Registration Dossier. [<https://echa.europa.eu/registration-dossier/-/registered-dossier/11796/7/6/2>].
- ECHA. Etidronic acid. REACH Registration Dossier. [<https://echa.europa.eu/registration-dossier/-/registered-dossier/16011>].
- ECHA. Fatty acids, C16-18 and C18-unsatd., Me esters. REACH Registration Dossier. [<https://echa.europa.eu/registration-dossier/-/registered-dossier/15554/1>].
- ECHA. Formamide. REACH Registration Dossier. [<https://echa.europa.eu/registration-dossier/-/registered-dossier/14929/7/1>].
- ECHA. Glycerides, tall-oil mono-, di-, and tri-. REACH Registration Dossier. [<https://echa.europa.eu/registration-dossier/-/registered-dossier/13204>].
- ECHA. Glycollic acid. REACH Registration Dossier. [<https://echa.europa.eu/registration-dossier/-/registered-dossier/14561/7/1>].
- ECHA. Icos-1-ene. REACH Registration Dossier. [<https://echa.europa.eu/registration-dossier/-/registered-dossier/15198/1>].
- ECHA. Isopropylamine. REACH Registration Dossier. [<https://echa.europa.eu/registration-dossier/-/registered-dossier/14604>].
- ECHA. Isotridecanol, ethoxylated. REACH Registration Dossier. [<https://echa.europa.eu/registration-dossier/-/registered-dossier/13803>].
- ECHA. Nitrilotrimethylenetris(phosphonic acid): REACH Registration Dossier. [<https://echa.europa.eu/registration-dossier/-/registered-dossier/15198/1>].
- ECHA. Pentadecane, 7-methylene: REACH Registration Dossier. [<https://echa.europa.eu/registration-dossier/-/registered-dossier/10654/1>].
- ECHA. Pentasodium (carboxylatomethyl)iminobis(ethylenenitrilo)tetraacetate. REACH Registration Dossier. [<https://echa.europa.eu/registration-dossier/-/registered-dossier/14364/7/1>].
- ECHA. Peracetic acid. REACH Registration Dossier. [<https://echa.europa.eu/registration-dossier/-/registered-dossier/14885/7/1>].

- ECHA. Phosphonic acid. REACH Registration Dossier. [<https://echa.europa.eu/registration-dossier/-/registered-dossier/15806/7/1>].
- ECHA. Piperazine. REACH Registration Dossier. [<https://echa.europa.eu/registration-dossier/-/registered-dossier/14941>].
- ECHA. Poly(oxy-1,2-ethanediyl), α -hydro- ω -hydroxy- Ethane-1,2-diol, ethoxylated. REACH Registration Dossier. [<https://echa.europa.eu/registration-dossier/-/registered-dossier/11848>].
- ECHA. Quaternary ammonium compounds, trimethylsoya alkyl, chlorides. REACH Registration Dossier. [<https://echa.europa.eu/registration-dossier/-/registered-dossier/25410>].
- ECHA. Sodium chlorate. REACH Registration Dossier. [<https://echa.europa.eu/registration-dossier/-/registered-dossier/14688>].
- ECHA. Sodium hydrogensulfite. REACH Registration Dossier. [<https://echa.europa.eu/registration-dossier/-/registered-dossier/15334>].
- ECHA. Solvent naphtha (petroleum), heavy arom. REACH Registration Dossier. [<https://echa.europa.eu/registration-dossier/-/registered-dossier/15728/7/1>].
- ECHA. Sulfonic acids, C14-16 (even numbered)-alkane hydroxy and C14-16 (even numbered)-alkene, sodium salts. REACH Registration Dossier. [<https://echa.europa.eu/registration-dossier/-/registered-dossier/16004>].
- ECHA. Tetrakis(hydroxymethyl)phosphonium sulphate(2:1). REACH Registration Dossier. [<https://echa.europa.eu/registration-dossier/-/registered-dossier/22979>].
- ECHA. Tridecane. REACH Registration Dossier. [<https://echa.europa.eu/registration-dossier/-/registered-dossier/14245/7/6/1>].
- ECHA. Troclosene sodium. REACH Registration Dossier. [<https://echa.europa.eu/registration-dossier/-/registered-dossier/14822/7/6/2>].
- ECHA. Undecane. REACH Registration Dossier. [<https://echa.europa.eu/registration-dossier/-/registered-dossier/2075/1>].
- Ellenhorn, M.J. and Barceloux, D.G., 1988. Medical Toxicology: Diagnosis and Treatment of Human Poisoning. ELSEVIER, NEW YORK, NY(USA). 1988.
- Fakhru'l-Razi, A., Pendashteh, A., Abdullah, L.C., Biak, D.R.A., Madaeni, S.S. and Abidin, Z.Z., 2009. Review of technologies for oil and gas produced water treatment. Journal of hazardous materials, 170(2-3), pp.530-551.
- Guerra K., Dahm K. and Dundorf S. (2011). Oil and gas produced water management and beneficial use in the Western United States. [Online]. <http://www.usbr.gov/research/AWT/reportpdfs/report157.pdf>

- Fillo, J.P., Koraido, S.M. and Evans, J.M., 1992. Sources, characteristics, and management of produced waters from natural gas production and storage operations. In *Produced Water* (pp. 151-161). Springer, Boston, MA.
- FDA. 2005. Guidance for industry: estimating the maximum safe starting dose in initial clinical trials for therapeutics in adult healthy volunteers. Center for Drug Evaluation and Research (CDER), p.7.
- FDA. SCOGS. Select Committee on GRAS Substances. Food Ingredient and Packaging Inventory. FDA Office of Food Safety and Applied Nutrition. [<https://www.accessdata.fda.gov/scripts/fdcc/?set=SCOGS>]. Accessed 12/2/2018
- Fleischman, R.W., Baker, J.R., Hagopian, M., Wade, G.G., Hayden, D.W., Smith, E.R., Weisburger, J.H. and Weisburger, E.K., 1980. Carcinogenesis bioassay of acetamide, hexanamide, adipamide, urea and P-tolylurea in mice and rats. *Journal of environmental pathology and toxicology*, 3(5-6), pp.149-170.
- Flynn, S.A., Butler, E.J. and Vance, I., 1996. Produced water composition, toxicity, and fate. In *Produced Water 2* (pp. 69-80). Springer, Boston, MA.
- Gosselin, R.E., H.C. Hodge, R.P. Smith, and M.N. Gleason. 1976. *Clinical Toxicology of Commercial Products*. 4th ed. Baltimore: Williams and Wilkins, 1976., p. II-181.
- Gosselin, R.E., R.P. Smith, H.C. Hodge. 1984. *Clinical Toxicology of Commercial Products*. 5th ed. Baltimore: Williams and Wilkins, 1984., p. II-186
- Gu, Z.P., Mao, B.Y., Wang, Y.X., Zhang, R.A., Tan, Y.Z., Chen, Z.X., Cao, L., You, G.D. and Segal, S.J., 2000. Low dose gossypol for male contraception. *Asian journal of andrology*, 2(4), pp.283-287.
- Gudelsky, G.A., Apud, J.A., Masotto, C., Locatelli, V., Cocchi, D., Racagni, G. and Müller, E.E., 1983. Ethanolamine-O-sulfate enhances γ -aminobutyric acid secretion into hypophyseal portal blood and lowers serum prolactin concentrations. *Neuroendocrinology*, 37(5), pp.397-399.
- Guerra, K., Dahm, K. and Dundorf, S., 2011. Oil and gas produced water management and beneficial use in the Western United States. US Department of the Interior, Bureau of Reclamation. <https://www.usbr.gov/research/dwpr/reportpdfs/report157.pdf>
- Halder, C.A., Holdsworth, C.E., Cockrell, B.Y. and Piccirillo, V.J., 1985. Hydrocarbon nephropathy in male rats: identification of the nephrotoxic components of unleaded gasoline. *Toxicology and industrial health*, 1(3), pp.67-87.
- HAZMAP, Pine Oil. Haz-Map: Information on Hazardous Chemicals and Occupational Diseases. <https://hazmap.nlm.nih.gov/category-details?id=9468&table=copytblagents>.
- Hellwig, J. and Liberacki, A.B., 1997. Evaluation of the pre-, peri-, and postnatal toxicity of monoethanolamine in rats following repeated oral administration during organogenesis. *Toxicological Sciences*, 40(1), pp.158-162.

- Howard, J.L., Cooper, B.R., White, H.L., Soroko, F.E. and Maxwell, R.A., 1980. A role for GABA in the control of ingestive behavior in rats: effects of ethanolamine-O-sulfate and muscimol. *Brain Research Bulletin*, 5, pp.595-599.
- IARC. 1978. The International Agency for Research on Cancer. Monographs on the evaluation of the carcinogenic risk of chemicals to humans. Volume 17. Some N-nitroso compounds. IARC, World Health Organization, Lyon, France.
- IARC. 2010a. Working Group on the Evaluation of Carcinogenic Risks to Humans, Some non-heterocyclic polycyclic aromatic hydrocarbons and some related exposures. IARC monographs on the evaluation of carcinogenic risks to humans, 92.
- IARC. 2010b. International Agency for Research on Cancer. Alcohol consumption and ethyl carbamate (Vol. 96). IARC Press, International Agency for Research on Cancer.
- IARC. 2013. International Agency for Research on Cancer. IARC monographs on the evaluation of carcinogenic risks to humans, volume 101. Some Chemicals Present in Industrial and Consumer Products, Food and Drinking-water, Coconut oil diethanolamine condensate. Lyon, France: IARC; 2013 [<https://monographs.iarc.fr/wp-content/uploads/2018/06/mono101-005.pdf>]. Accessed 12/2/2018.
- IPCS. 1982. Toxicological evaluation of certain food additives. FAO/WHO Expert Committee on Food Additives, International Programme on Chemical Safety, World Health Organization, Geneva, Switzerland.
- IOM. 1997. Institute of Medicine (IOM). Food and Nutrition Board. Dietary Reference Intakes: Calcium, Phosphorus, Magnesium, Vitamin D and Fluoride. External link disclaimer. Washington, DC: National Academy Press, 1997.
- Ishidate Jr, M., Sofuni, T., Yoshikawa, K., Hayashi, M., Nohmi, T., Sawada, M. and Matsuoka, A., 1984. Primary mutagenicity screening of food additives currently used in Japan. *Food and Chemical Toxicology*, 22(8), pp.623-636.
- Jiménez, S., Micó, M.M., Arnaldos, M., Medina, F. and Contreras, S., 2018. State of the art of produced water treatment. *Chemosphere*, 192, pp.186-208.
- Kelly, C.M., DeMerlis, C.C., Schoneker, D.R. and Borzelleca, J.F., 2003. Subchronic toxicity study in rats and genotoxicity tests with polyvinyl alcohol. *Food and chemical toxicology*, 41(5), pp.719-727.
- Klaassen, C.D. and Watkins, J.B. eds., 1996. Casarett and Doull's toxicology: the basic science of poisons (Vol. 5). New York: McGraw-Hill.
- Kuo, H.W., Lai, J.S., Lin, M. and Su, E.S., 1997. Effects of exposure to carbon disulfide (CS₂) on electrocardiographic features of ischemic heart disease among viscose rayon factory workers. *International archives of occupational and environmental health*, 70(1), pp.61-66.
- Lamot, E. and Voets, J.P., 1978. Microbial biodegradation of cellophane. *Zeitschrift für allgemeine Mikrobiologie*, 18(3), pp.183-188.

- Lanigan, R. S., and T. A. Yamarik. "Final report on the safety assessment of EDTA, calcium disodium EDTA, diammonium EDTA, dipotassium EDTA, disodium EDTA, TEA-EDTA, tetrasodium EDTA, tripotassium EDTA, trisodium EDTA, HEDTA, and trisodium HEDTA." *International Journal of Toxicology* 21 (2002): 95-142.
- Laurence, D.R., 1977. Clinical Toxicology of Commercial Products. Acute Poisoning. *Journal of clinical pathology*, 30(2), p.193.
- Madsen, T., Boyd, H.B., Nylén, D., Pedersen, A.R., Petersen, G.I. and Simonsen, F., 2001. Environmental and health assessment of substances in household detergents and cosmetic detergent products. *Environmental Project*, 615(2001), p.221.
- Martel-Valles, José Fernando, Adalberto Benavides-Mendoza, Luis Alonso Valdez-Aguilar, Antonio Juárez-Maldonado, and Norma Angélica Ruiz-Torres. "Effect of the application of produced water on the growth, the concentration of minerals and toxic compounds in tomato under greenhouse." *Journal of environmental protection* 4, no. 07 (2013): 138.
- Manfra, L., Maggi, C., Bianchi, J., Mannozi, M., Faraponova, O., Mariani, L., Onorati, F., Tornambè, A., Lamberti, C.V. and Magaletti, E., 2010. Toxicity evaluation of produced formation waters after filtration treatment. *Natural Science*, 2(01), p.33.
- Meagher, R.B., 2000. Phytoremediation of toxic elemental and organic pollutants. *Current opinion in plant biology*, 3(2), pp.153-162.
- MeSH, Ethanolamine-O-Sulfate. NIH Medical Subject Headings. Ethanolamine O-sulfate [Supplementary Concept]. [<https://www.ncbi.nlm.nih.gov/mesh/67020619>] Accessed 12/2/2018
- Mezei, M., 1975. Effect of polysorbate 85 on human skin. *Journal of Investigative Dermatology*, 64(3), pp.165-168.
- Mizumoto, A., Ohashi, S., Hirohashi, K., Amanuma, Y., Matsuda, T. and Muto, M., 2017. Molecular mechanisms of acetaldehyde-mediated carcinogenesis in squamous epithelium. *International journal of molecular sciences*, 18(9), p.1943.
- Brooks, P.J. and Theruvathu, J.A., 2005. DNA adducts from acetaldehyde: implications for alcohol-related carcinogenesis. *Alcohol*, 35(3), pp.187-193.
- Moody, D.E. and Reddy, J.K., 1978. Hepatic peroxisome (microbody) proliferation in rats fed plasticizers and related compounds. *Toxicology and applied pharmacology*, 45(2), pp.497-504.
- Moretto, Hans-Heinrich; Schulze, Manfred; Wagner, Gebhard. 2005. "Silicones". *Ullmann's Encyclopedia of Industrial Chemistry*. Weinheim: Wiley-VCH. doi:10.1002/14356007.
- Mortensen, A., Aguilar, F., Crebelli, R., Di Domenico, A., Dusemund, B., Frutos, M.J., Galtier, P., Gott, D., Gundert-Remy, U., Leblanc, J.C. and Lindtner, O., 2017. Re-evaluation of fatty acids (E 570) as a food additive. *EFSA Journal*, 15(5).

- NAS. 2000. Toxicological risks of selected flame-retardant chemicals. National Academy of Sciences, National Research Council. Washington, DC: The National Academies Press.
- Negri, M.C., Hinchman, R.R. and Gatliff, E.G., 1996. Phytoremediation: using green plants to clean up contaminate soil, groundwater, and wastewater (No. ANL/ES/CP-89941; CONF-960804-38). Argonne National Lab., IL (United States).
- Neff, J.M. and Sauer, T.C., 1996. Aromatic hydrocarbons in produced water. In Produced Water 2 (pp. 163-175). Springer, Boston, MA.
- NTP (National Toxicology Program) (1999) Toxicology and carcinogenesis studies of furfuryl alcohol in F344/N rats and B6C3F1 mice (inhalation studies). US Department of Health and Human Services, Public Health Service, National Institutes of Health. National Toxicology Program, Research Triangle Park, NC, USA.
- Odom, I.E., 1984. Smectite clay minerals: properties and uses. Phil. Trans. R. Soc. Lond. A, 311(1517), pp.391-409.
- Otto, G.H., 1989, A national survey of naturally occurring radioactive materials (NORM) in petroleum producing and gas processing facilities: American Petroleum Institute, Dallas, Texas, 265 p.
- Passi, S., Nazzaro-Porro, M., Picardo, M., Mingrone, G. and Fasella, P., 1983. Metabolism of straight saturated medium chain length (C9 to C12) dicarboxylic acids. Journal of lipid research, 24(9), pp.1140-1147.
- Patnaik, 1992. A Comprehensive Guide to the Hazardous Properties of Chemical Substances, Van Nostrand Reinhold, 1992.
- Peuke, A.D., Rokitta, M., Zimmermann, U., Schreiber, L. and Haase, A., 2001. Simultaneous measurement of water flow velocity and solute transport in xylem and phloem of adult plants of *Ricinus communis* over a daily time course by nuclear magnetic resonance spectrometry. Plant, Cell & Environment, 24(5), pp.491-503.
- Potakar. 1983. 28-Tage-Test mit Antischaummittel Sj/Sb nach wiederholter oraler Verabreichung an Ratten. Testinglaboratory: Institut für Toxikologie, Henkel KGaA, Düsseldorf, Germany. Report no.: R9501060. Owner company: Henkel KGaA, Düsseldorf, Germany. Report date: 1983-05-01.
- Procter and Gamble Ltd. (1974). Ninety-day rat feeding study on Neodol 45-7. Unpublished report.
- Procter and Gamble Ltd. (1978). 91-day subchronic feeding study. Unpublished report. Shell Chemical Company. Human safety of Neodol products. Unpublished report.
- Robinson, E.C. and Schroeder, R.E., 1992. Reproductive and developmental toxicity studies of a linear alkylbenzene mixture in rats. Fundamental and Applied Toxicology, 18(4), pp.549-556.

- Røe Utvik, Toril I., and Jon Rytter Hasle. "Recent knowledge about produced water composition, and the contribution from different chemicals to risk of harmful environmental effects." In SPE International Conference on Health, Safety and Environment in Oil and Gas Exploration and Production. Society of Petroleum Engineers, 2002.
- Rowe, R.C., Sheskey, P.J. and Owen, S.C. eds., 2006. Handbook of pharmaceutical excipients (Vol. 6). London: Pharmaceutical press.
- Scailteur, V., Maurer, J.K., Walker, A.P. and Calvin, G., 1986. Subchronic oral toxicity testing in rats with a liquid hand-dishwashing detergent containing anionic surfactants. Food and chemical toxicology, 24(2), pp.175-181.
- Simamora, P. and Chern, W., 2006. Poly-L-lactic acid: an overview. Journal of drugs in dermatology: JDD, 5(5), pp.436-440.
- Skaare, B.B., Kihle, J. and Torsvik, T., 2011. Biodegradation of crude oil as potential source of organic acids in produced water. In Produced Water (pp. 115-126). Springer, New York, NY.
- Snellings, W. M., McMartin, K. E., Banton, M. I., Reitman, F., & Klapacz, J. (2017). Human health assessment for long-term oral ingestion of diethylene glycol. Regulatory Toxicology and Pharmacology, 87, S1-S20.
- Societe Francaise Hoechst (1987). Glyoxal 40. 28 day dose range finding study in rats by administration in drinking water. Unpublished report (Study No. 2619 TSR; HOE 87.1678) [cited in BUA, 1997].
- Stellman, J.M. ed., 1998. Encyclopaedia of occupational health and safety (Vol. 1). International Labour Organization.
- Strømgren, T., Sørstrøm, S.E., Schou, L., Kaarstad, I., Aunaas, T., Brakstad, O.G. and Johansen, Ø., 1995. Acute toxic effects of produced water in relation to chemical composition and dispersion. Marine Environmental Research, 40(2), pp.147-169.
- Szycher M et al. 2014. Biomaterials, Prosthetics, and Biomedical Devices. Kirk-Othmer Encyclopedia of Chemical Technology (1999-2015). John Wiley & Sons, Inc.
- Tall oil. 1989. '8 Final Report on the Safety Assessment of Tall Oil Acid' (1989) Journal of the American College of Toxicology, 8(4), pp. 769–776. doi: 10.3109/10915818909010530.
- Teranishi, R., Schultz, T.H., McFadden, W.H., Lundin, R.E. and Black, D.R., 1963. Volatiles from Oranges. 1. Hydrocarbons. Identified by Infrared, Nuclear Magnetic Resonance, and Mass Spectra. Journal of Food Science, 28(5), pp.541-545.
- TOXNET. 1991. HSDB: Ammonium Benzoate. Toxnet, Toxicology Data Network: Hazardous Substance Data Bank. [<https://toxnet.nlm.nih.gov/cgi-bin/sis/search2/f?./temp/~KMUX2L:1>] Accessed 12/2/2018.
- TOXNET. 2004. HSDB: Hydroacetic Acid. Toxnet, Toxicology Data Network: Hazardous Substance Data Bank. [<https://toxnet.nlm.nih.gov/cgi-bin/sis/search2/f?./temp/~J3LNJq:1>] Accessed 12/2/2018.

- TOXNET. 2014. HSDB: Hydroxyacetic acid. Toxnet, Toxicology Data Network: Hazardous Substance Data Bank. [<https://toxnet.nlm.nih.gov/cgi-bin/sis/search2/f?./temp/~XqdW9f:3>] Accessed 12/2/2018.
- TOXNET. 2015a. HSDB: Ammonium Chloride. Toxnet, Toxicology Data Network: Hazardous Substance Data Bank. [<https://toxnet.nlm.nih.gov/cgi-bin/sis/search2/r?dbs+hsdb:@term+@DOCNO+483>] Accessed 12/2/2018.
- TOXNET. 2015b. HSDB: Potassium Hydroxide. Toxnet, Toxicology Data Network: Hazardous Substance Data Bank. [<https://toxnet.nlm.nih.gov/cgi-bin/sis/search2/f?./temp/~WB3WST:3>] Accessed 12/2/2018.
- TOXNET. 2016. HSDB: Polyvinyl Alcohol. Toxnet, Toxicology Data Network: Hazardous Substance Data Bank. Reviewed 1/14/2016. [<https://toxnet.nlm.nih.gov/cgi-bin/sis/search2/f?./temp/~SA61gU:1>] Accessed 12/2/2018.
- Unilever. (1978a). Feeding studies on Alfol 12-14 E7. Part 2. Thirteen-week test in rats. Unpublished report.
- Unilever. (1978b). Feeding studies on Lial 12-15 E7. Part 2. Thirteen-week test in rats. Unpublished report.
- US EPA. 1990. IRIS Summary: Benzo[g,h,i]perylene. U.S Environmental Protection Agency. [https://cfpub.epa.gov/ncea/iris/iris_documents/documents/subst/0461_summary.pdf]. Accessed 12/2/2018.
- US EPA 1991. Reregistration Eligibility Document Facts: Sulfur. US EPA, Pesticides and Toxic Substances, Washington, DC.
- US EPA. 2001. IRIS Toxicological Review of Methyl Chloride. U.S. Environmental Protection Agency, Washington, DC, EPA/635/R01/003, 2001.
- US EPA. 2002. A review of the reference dose and reference concentration processes. U.S. Environmental Protection Agency, Washington, DC, EPA/630/P-02 F, Final Report.
- U.S. EPA. 2008. IRIS Toxicological Review of Propionaldehyde. U.S. Environmental Protection Agency, Washington, DC, EPA/635/R-08/003F, 2008.
- US EPA. 2016a. Final rule. D-glucurono-6-deoxy-L-manno-Dglucan, Acetate, Calcium Magnesium Potassium Sodium Salt (Diutan Gum); Exemption From the Requirement of a Tolerance. Federal Register / Vol. 81, No. 113 / Monday, June 13, 2016 / Rules and Regulations pg. 38101.
- US EPA, 2016b. United State Environmental Protection Agency. Toxicological Review of Ammonia Noncancer Inhalation. EPA/635/R-16/163Fa. September, 2016. [https://cfpub.epa.gov/ncea/iris2/chemicalLanding.cfm?&substance_nmbr=422]. Accessed 12/2/2018.

- US EPA, PPRTV. Provisional Peer Reviewed Toxicity Values. U.S. Environmental Protection Agency. Superfund Health Risk Technical Support Center National Center for Environmental Assessment Office of Research and Development. <https://www.epa.gov/pprtv> . Accessed 2/16/2019.
- Utvik, T.I.R., 1999. Chemical characterisation of produced water from four offshore oil production platforms in the North Sea. *Chemosphere*, 39(15), pp.2593-2606.
- Van, J.M. and Ballantyne, B., 2001. Subchronic peroral toxicity of triethylene glycol in the Fischer 344 rat. *Veterinary and human toxicology*, 43(5), pp.269-276.
- Vázquez-Rodríguez, G.A., Beltrán-Hernández, R.I., Coronel-Olivares, C. and Rols, J.L., 2011. Standardization of activated sludge for biodegradation tests. *Analytical and bioanalytical chemistry*, 401(4), p.1127.
- Veil, J.A., Puder, M.G., Elcock, D. and Redweik Jr, R.J., 2004. A white paper describing produced water from production of crude oil, natural gas, and coal bed methane (No. ANL/EA/RP-112631). Argonne National Lab., IL (US).
- Webb, D.R., Ridder, G.M. and Alden, C.L., 1989. Acute and subchronic nephrotoxicity of d-limonene in Fischer 344 rats. *Food and chemical toxicology*, 27(10), pp.639-649.
- Weiner, M.L., Freeman, C., Trochimowicz, H., De Gerlache, J., Jacobi, S., Malinverno, G., Mayr, W. and Regnier, J.F., 2000. 13-week drinking water toxicity study of hydrogen peroxide with 6-week recovery period in catalase-deficient mice. *Food and chemical toxicology*, 38(7), pp.607-615.
- WHO. 1996. Linear alkylbenzene sulfonates and related compounds. Geneva : World Health Organization. <http://www.who.int/iris/handle/10665/37830>
- WHO. 2009. Bromide in drinking-water: Background document for development of WHO Guidelines for Drinking-water Quality. World Health Organization, WHO Press, World Health Organization, Switzerland. WHO/HSE/WSH/09.01/6. https://www.who.int/water_sanitation_health/dwq/chemicals/Fourth_Edition_Bromide_Final_January_2010.pdf
- WHO. 2017a. Guidelines for Drinking-Water Quality: Fourth Edition Incorporating the First Addendum. Geneva: World Health Organization; 2017. Ch. 10, Acceptability aspects: Taste, odour and appearance. Available from: <https://www.ncbi.nlm.nih.gov/books/NBK442378/>
- WHO. 2017b. Guidelines for Drinking-Water Quality: Fourth Edition Incorporating the First Addendum. Geneva: World Health Organization; 2017. Ch. 12, Chemical fact sheets. [<https://www.ncbi.nlm.nih.gov/books/NBK442375/>]
- Wiles, M.C., Huebner, H.J., Afriyie-Gyawu, E., Taylor, R.J., Bratton, G.R. and Phillips, T.D., 2004. Toxicological evaluation and metal bioavailability in pregnant rats following exposure to clay minerals in the diet. *Journal of Toxicology and Environmental Health, Part A*, 67(11), pp.863-874.

Zielinski, R.A. and Otton, J.K., 1999. Naturally Occurring Radioactive Materials (NORM) in Produced Water and Oil-field Equipment: An Issue for Energy Industry. US Department of the Interior, US Geological Survey.

Zoltan, A., Williams, R.B., International Programme on Chemical Safety. 2005. Bentonite, kaolin and selected clay minerals. Geneva : World Health Organization.
[<http://www.who.int/iris/handle/10665/43102>] Accessed 12/2/2018

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TABLES

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Table 1: Allometric scaling values for converting animal to human doses (FDA, 2005)

Species	Body Surface Area (square meters)	Allometric Scaling Value
Mouse	0.007	12.3
Hamster	0.016	7.4
Rat	0.025	6.2
Guinea Pig	0.05	4.6
Rabbit	0.15	3.1
Dog	0.5	1.8
Monkeys (rhesus)	0.25	3.1
Baboon	0.60	1.8
Micro pig	0.74	1.4
Mini pig	1.14	1.1
Human ⁴	1.7 (f) and 2.0 (m)	1.0

⁴ The estimates for female (f) and male (m) body surface area average estimates not included on the FDA allometric scaling list but are added for comparison and extracted from the U.S. NCHS National Health and Nutrition Examination Survey (2011-2014).

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Table 2: Chemical additives identified as GRAS or non-toxic

CASRN	Chemical Name	Assessment Classification	Additional Notes
64-19-7	Acetic acid	GRAS	
90320-37-9	Almond Shell	Considered virtually non-toxic	
12125-02-9	Ammonium Chloride	Medication	See main text (TOXNET, 2015a)
1302-78-9	Bentonite	GRAS	Bulk laxative
No CASRN	Bicarbonate	Food additive	
7440-70-2	Calcium	Dietary requirement	
471-34-1	Calcium carbonate	GRAS	Antacid
1305-78-8	Calcium Oxide	Destroyed upon contact with water	
7778-18-9	Calcium sulfate	Food additive	
7440-44-0	Carbon	GRAS	
124-38-9	Carbon dioxide	Food additive	
No CASRN	Carbonate	Food additive	
No CASRN	Cedar fiber	Considered virtually non-toxic	Wood fiber
9005-81-6	Cellophane	GRAS	See main text on cellophane
9004-34-6	Cellulose, microcrystalline	GRAS	
16887-00-6	Chloride (Cl ⁻)	Ion found in food additives	
77-92-9	Citric acid	GRAS	
63148-62-9	Dimethyl siloxanes and silicones	Considered virtually non-toxic	See main text (Moretto et al., 2005)
7758-16-9	Disodium pyrophosphate	Food additive	
64-17-5	Ethanol	Food additive	
84012-43-1	Extract of walnut	Considered virtually non-toxic	Walnut shell powder

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Table 2 continued... Chemical additives identified as GRAS or non-toxic

CASRN	Chemical Name	Assessment Classification	Additional Notes
61790-12-3	Fatty acids, tall-oil	Food additive	Tall Oil Acid is approved for use as an indirect food additive. When fed to rats as 15% of the total caloric intake, Tall Oil Acid was nontoxic; however, it had a growth-retarding effect. No treatment-related effects were observed in rats fed diets containing 5% and 10% Tall Oil Acid over two generations. (Tall oil, 1989)
61790-45-2	Fatty acids, tall-oil, sodium salts	Food additive	See Fatty acids, tall-oil
56-81-5	Glycerol	Food additive	
7782-42-5	Graphite	Considered virtually non-toxic	
7647-01-0	Hydrochloric Acid	Considered virtually non-toxic	See main text
9004-62-0	Hydroxyethyl cellulose	GRAS	See main text (Bingham et al., 2001)
7439-90-9	Krypton	Inert gas	
1317-65-3	Limestone	Health supplement	Contains calcium carbonate
7439-95-4	Magnesium	Health Supplement	See main text (IOM, 1997)
No CASRN	Magma fiber	Inert mineral	
1302-93-8	Mullite	Inert mineral	Does not dissolve in water
7727-37-9	Nitrogen	Inert gas	
No CASRN	Nutshell	Considered virtually non-toxic	
112-80-1	Oleic acid	GRAS	
7440-09-7	Potassium	Dietary requirement	
13397-24-5	Phosphogypsum [Gypsum]	GRAS	Gypsum is made of Calcium Sulfate, which is GRAS
7723-14-0	Phosphorous	Dietary requirement	Toxicity concern, white phosphorus (very unlikely to be found)
No CASRN	Polydimethylsiloxane emulsion	Considered virtually non-toxic	See main text (Moretto et al., 2005)
74-84-0	Polyethylene [Ethane]	Inert	See main text (Snyder, 1987)

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Table 2 continued... Chemical additives identified as GRAS or non-toxic

CASRN	Chemical Name	Assessment Classification	Additional Notes
25038-59-9	Polyethylene terephthalate	Considered virtually non-toxic	Low oral toxicity, see main text (DAK Americas, 2008; Toker et al., 2012)
127-08-2	Potassium acetate	Food additive	
7447-40-7	Potassium chloride	GRAS	
12136-45-7	Potassium Oxide	Destroyed upon contact with water	
1319-41-1	Saponite	Food additive (animal)	See main text (Odem et al., 1984; Wiles et al., 2004; Zoltan et al., 2005)
1318-93-0	Smectite	Food additive (animal)	See main text (Odem et al., 1984; Wiles et al., 2004; Zoltan et al., 2005)
7440-23-5	Sodium	Dietary requirement	
127-09-3	Sodium acetate	GRAS	
532-32-1	Sodium benzoate	GRAS	
144-55-8	Sodium bicarbonate	GRAS	
497-19-8	Sodium carbonate	GRAS	
9004-32-4	Sodium carboxymethylcellulose	GRAS	
9063-38-1	Sodium carboxymethyl starch	GRAS	
7647-14-5	Sodium chloride	GRAS	
6381-77-7	Sodium erythorbate	GRAS	
7681-52-9	Sodium Hypochlorite	Food additive	Can be used to disinfect drinking water
7681-82-5	Sodium iodide	Food additive	
1313-59-3	Sodium Oxide	Destroyed upon contact with water	
7757-82-6	Sodium sulfate	Food additive	
7772-98-7	Sodium thiosulfate	GRAS	

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Table 2 continued... Chemical additives identified as GRAS or non-toxic

CASRN	Chemical Name	Assessment Classification	Additional Notes
9005-65-6	Sorbitan monooleate, ethoxylated	Considered virtually non-toxic	See main text (Rowe et al., 2006)
57-11-4	Stearic Acid	Food additive	(Mortensen et al., 2017)
No CASRN	Sulfate (SO_4^{2-})	Ion found in food additives	
7704-34-9	Sulfur	Poses little risk to humans or animals	(US EPA, 1991)
13463-67-7	Titanium dioxide	Food additive	
7732-18-5	Water	Considered virtually non-toxic	
No CASRN	Wood dust	Considered virtually non-toxic	Does not dissolve in water
11138-66-2	Xanthan gum	Food additive	
7440-63-3	Xenon	Inert Gas	

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Table 3: Chemicals with insufficient data to identify chronic toxicity

CASRN	Chemical Name	Alternate Chemical Name/Other Notes
479-66-3	1H, 3H-Pyrano (4,3-b)(1)benzopyran-9-carboxylic acid, 4,10-dihydro-3,7,8 trihydroxy-3-methyl-10-oxo	
27646-80-6	2-Methylamino-2-methyl-1-propanol	
67990-40-3	2-Propen-1-aminium, N,N-dimethyl-N-2-propenyl-, chloride, polymer with 2-hydroxypropyl 2-propenoate and 2-propenoic acid	
145417-45-4	2-Propenoic acid, 2-methyl-, polymer with methyl 2-methyl-2-propenoate, octadecyl 2-methyl 2 propenoate and 2propenoic acid, sodium salt	
9033-79-8	2-propenoic acid, polymer with sodium 2-propenoate	Sodium Acrylate Copolymer (absorbant polymer)
130800-24-7	2-Propenoic acid, telomer with 2-methyl-2-(1-oxo-2-propenyl)-1-propanesulfonic acid, sodium salt	
300-92-5	Aluminum distearate	
No CASRN	Amide surfactant acid salt	
No CASRN	Amides, Non Ionics	
61791-24-0	Amine derivative	Polyethylene glycol soyamine
67924-33-8	Amine salt	Ethanol, 2,2',2"-nitrilotris-, homopolymer, hydrochloride
NP-U2856	Amine salt	
64346-44-7	Amine sulfate	Bis(isopropylammonium) sulphate
1863-63-4	Ammonium benzoate	Chronic toxicity is unknown, as evaluations are all for acute exposures. Exposures ranging from 14-1000 mg/kg/day caused non-lethal acute affects. (TOXNET, 1991).
69418-26-4	Cationic acrylamide copolymer	Polyquaternium-33
44992-01-0	Cationic acrylamide monomer	2-(Dimethylamino)ethyl acrylate methochloride; Ethanaminium, N,N,N-trimethyl-2-[(1-oxo-2-propenyl)oxy]-, chloride
54076-97-0	Cationic polymer	Ethanaminium, N,N,N-trimethyl-2-[(1-oxo-2-propenyl)oxy]-, chloride, homopolymer
681331-04-4	Causticized Lignite	
64743-05-1	Coke (petroleum), calcined	
25987-30-8	Copolymer of acrylamide and sodium acrylate	2-Propenoic acid, polymer with 2-propenamide, sodium salt
129828-31-5	Crosslinked polyol ester	2-Propenoic acid, polymer with 4-(1,1-dimethylethyl)phenol, formaldehyde, 2,5-furandione, 2-methyloxirane, 4-nonylphenol and oxirane
25155-15-1	Cymenes	p-Cymene is a known volatile compound in oranges (Teranishi et al., 1963).
2673-22-5	Diester of sulfosuccinic acid sodium salt	
No CASRN	Drilling paper	

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Table 3 continued... Chemicals with insufficient data to identify chronic toxicity

CASRN	Chemical Name	Alternate Chemical Name/Other Notes
61791-26-2	Ethoxylated amine	PEG-10 Hydrogenated tallow amine
9081-83-8	Ethoxylated octylphenol	
5877-42-9	Ethyl octynol	4-Ethyl-3-hydroxy-1-octyne
63428-92-2	Formaldehyde, polymer with 2-methyloxirane, 4-nonylphenol and oxirane	p-Nonylphenol, formaldehyde copolymer, ethoxylated and propoxylated
30704-64-4	Formaldehyde, polymer with 4-(1,1-dimethylethyl)phenol, 2-methyloxirane and oxirane	p-tert-Butylphenol-formaldehyde resin, copolymer with ethylene oxide and propylene oxide
30846-35-6	Formaldehyde, polymer with 4-nonylphenol and oxirane	
No CASRN	Heavy catalytic reformed naptha	
129521-66-0	Lignite	
No CASRN	Methyl ester of sulfonated tannin	
PE-M2464	Methyl oxirane polymer	
No CASRN	Organic acid ethoxylated alcohols	
68171-44-8	Oxyalkylated alkylphenolic resin	Formaldehyde, polymer with 4-(1,1-dimethylethyl)phenol, 4-nonylphenol and oxirane
68910-19-0	Oxyalkylated polyamine	Diethylenetriamine, propoxylated, ethoxylated
67939-72-4	Oxyalkylated polyamine	Triethylenetetramine polymer with oxirane and methyl oxirane
68123-18-2	Phenol, 4,4'-(1-methylethylidene) bis-, polymer with 2-(chloromethyl)oxirane, 2-methyloxirane and oxirane	
68425-75-2	Phosphate ester salt	Ethanol, 2-amino-, polymer with alpha-tridecyl-omega-hydroxypoly(oxy-1,2-ethanediyl) phosphate
9005-70-3	POE (20) Sorbitan Trioleate	Polysorbate 85. No chronic oral studies are available, dermal studies show minor erythema (Mezei., 1975).
9003-79-8	Polyacrylate	Polyacrylamide/Polyacrylate Polymer Blend.
68955-69-1	Polyamine salts	Hexanedinitrile, hydrogenated, high-boiling fraction, polymer with epichlorohydrin, acetate (salt)
26062-79-3	Polydimethyl diallyl ammonium chloride	Polyquaternium-6; Quaternium-40
68036-92-0	Polyglycol diepoxide	Oxirane, methyl-, polymer with oxirane, ether with 1,2,3-propanetriol (3:1), ether with (chloromethyl)oxirane polymer with 4,4'-(1-methylethylidene)bis(phenol)
68036-95-3	Polyglycol diepoxide	Oxirane, methyl-, polymer with oxirane, ether with (chloromethyl)oxirane polymer with 4,4'-(1-methylethylidene)bis(phenol)
9038-95-3	Polyglycol ether	Oxirane, methyl, polymer and oxirane, butyl ether
No CASRN	Polyhydroxyalkanoates (PHA)	

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Table 3 continued... Chemicals with insufficient data to identify chronic toxicity

CASRN	Chemical Name	Alternate Chemical Name/Other Notes
64741-71-5	Polymers (petroleum) viscous	TSCA Definition 2018: A complex combination of hydrocarbons obtained from distillation of products from the polymerization of propylene or butylene. It has a carbon number range from C12 upward and a boiling range from approximately 220.degree.C (428.degree.F) upward. The hydrocarbons are predominantly monoolefinic.
36484-54-5	Polyoxyalkylene glycol	
61790-86-1	Polyoxyalkylenes	Fatty acids, tall-oil, monoesters with sorbitan, ethoxylated
9014-93-1	Polyoxyethylene dinonylphenol	Nonyl nonoxynol-10
12068-19-8	Polyoxyethylene nonyl phenyl ether phosphate	PEG-6 Nonyl phenyl ether phosphate, sodium salt
70142-34-6	Polyoxyl 15 hydroxystearate	
42751-79-1	Polyquaternary amine	Dimethylamine, polymer with epichlorohydrin and ethylenediamine
68609-18-7	Quaternized condensed alkanolamines	Ethanol, 2,2',2''-nitrilotris-, homopolymer, reaction products with chloromethane
9003-04-7	Sodium polyacrylate	Polyacrylic acid, sodium salt;
No CASRN	Steranes or cyclopentanoperhydrophenanthrene	
72480-70-7	Tar bases, quinoline derivatives, quaternized benzyl chloride	
25265-78-5	Tetrapropylenebenzene (1-phenyldodecane)	
68527-49-1	Thiourea, polymer with formaldehyde and 1-phenylethanone	
64114-46-1	Triethanolamine homopolymer	

Table 4: Chemicals without chronic oral toxicity

CASRN	Chemical Name	Notes
629-73-2	1-Hexadecene	NOAEL > 1000mg/kg/day for females and males because the findings were not evidence of true systemic toxicity, as the compound was aspirated during delivery (ECHA, Hexadecene)
No CASRN	Alcohols, C-10-14 ethoxylated	Alcohol ethoxylates are a class of non-ionic surfactants with hundreds of different potential forms depending on length of the carbon chains and saturation arrangement. There is no published data suggesting chronic systemic human toxicity and in animal models, no health effects have been observed with repeated dose studies. In multiple 90-day repeated dose rat studies conducted by adding ethoxylated alcohols to food: adding C14-15 alcohol ethoxylates to food, no relevant local or systemic effects were observed with doses of 500 mg/kg/day (Procter and Gamble Ltd., 1978); adding C12-15 alcohol ethoxylates to food, no relevant local or systemic effect with dose of 102 mg/kg/day (Unilever, 1978a); adding C12-C14 alcohol ethoxylates to food, no relevant local or systemic effects with dose of 110 mg/kg/day; and adding C14-15 alcohol ethoxylates to food, no relevant local or systemic effects--including reproductive--were observed with daily dose of 785 mg/kg/day (Proctor and Gamble, 1974).
68551-12-2	Alcohols, C12-16, ethoxylated	See Alcohol, C-10-14 ethoxylated
68951-67-7	Alcohols, C14-C15, ethoxylated	See Alcohol, C-10-14 ethoxylated
No CASRN	Alcohols, C9-11, ethoxylated	See Alcohol, C-10-14 ethoxylated
90622-58-5	Alkanes, C11-15-iso	Using a read across study using other alkanes, no effects found in both rats and dogs (Johannsen and Levinskas, 1987); No effects observed in a study with C12-C14 isoalkane exposures up to 5000 mg/kg/day, as reported in the registration dossier for ECHA REACH program (ECHA, Alkanes, C12-14-iso).
90622-46-1	Alkanes, C14-16	See Dodecane, registration dossier reports toxicologic data for mixed hydrocarbons with length of 10 or more carbons.
926-39-6	Amine sulfate [Ethanolamine-O-sulfate]	Ethanolamine-O-sulfate has a known acute diuretic and enzymatic inhibitory effect; these effects are acute and transitory (MeSH, Ethanolamine-O-sulfate). In a study where rats were given 250 mg/kg and 500 mg/kg of ethanolamine-O-sulfate through repeated intraperitoneal injections, this produced decreases in body weight and increases in brain GABA levels (Howard et al., 1980). Ethanolamine-O-sulfate is a GABA transferase inhibitor, which will increase GABA levels in the brain. Most studies were found to give it intraventricularly, as it poorly crosses the blood brain barrier (Anlezark et al., 1976; Gudelsky et al., 1983). As such, chronic oral exposure is likely to be of minimal risk.

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Table 4 continued... Chemicals without chronic oral toxicity

CASRN	Chemical Name	Notes
7664-41-7	Ammonia	Ammonia is a gas with solubility in water; it creates a basic solution. For example, a 1 molar aqueous solution of ammonia has a pH of approximately 11.6, which is about 10 times less basic than household bleach, which can have pH as high as 12.6. Ammonia's toxicity in oral exposure is related to its caustic properties. In the context of using produced water for irrigation with ammonia, anhydrous ammonia is used as a fertilizer, and therefore unlikely to affect the quality of crops. It is not assessed under IRIS for oral exposure and not classifiable as a human carcinogen (US EPA, 2016b).
191-24-2	Benzo(ghi)perylene	Under IRIS, it is not assessed for oral exposure or classifiable as to human carcinogenicity (US EPA, 1990). Available studies were deemed by the EPA to be inadequate to make an assessment of carcinogenicity due to oral exposure, where they used lung implant, skin-painting and subcutaneous injection bioassays. Results from those studies do not suggest overt carcinogenicity (US EPA, 1990). It is also classified by IARC as Group 3 (Not classifiable as to its carcinogenicity to humans).
106-97-8	Butane	Butane is a gas with low toxicity with little risk of oral exposure. A 10-minute inhalation exposure at 10,000 ppm of butane gas results in drowsiness, but no other evidence of systemic effects (ACGIH, 2012).
68551-19-9	C12-C14 Isoalkanes	See Alkanes, C11-15-iso
68551-20-2	C12-C14 Isoalkanes	See Alkanes, C11-15-iso
61791-31-9	Cocamide DEA	Known risks associated with cocamide diethanolamine exposure are through dermal/inhalation exposures (IARC, 2013)
14464-46-1	Crystalline silica (cristobalite)	The route of exposure of concern for crystalline silica is inhalation. The available data are insufficient to demonstrate an association for an adverse outcome with oral exposure (ATSDR, 2017).
14808-60-7	Crystalline silica (quartz)	The route of exposure of concern for crystalline silica is inhalation. The available data are insufficient to demonstrate an association for an adverse outcome with oral exposure (ATSDR, 2017).
14808-60-7	Crystalline silica (quartz)	The route of exposure of concern for crystalline silica is inhalation. The available data are insufficient to demonstrate an association for an adverse outcome with oral exposure (ATSDR, 2017).
15468-32-3	Crystalline silica (tridymite)	The route of exposure of concern for crystalline silica is inhalation. The available data are insufficient to demonstrate an association for an adverse outcome with oral exposure (ATSDR, 2017).
15468-32-3	Crystalline silica (tridymite)	The route of exposure of concern for crystalline silica is inhalation. The available data are insufficient to demonstrate an association for an adverse outcome with oral exposure (ATSDR, 2017).

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Table 4 continued... Chemicals without chronic oral toxicity

CASRN	Chemical Name	Notes
10042-91-8	Diphosphoric acid, sodium salt	Polyphosphates have low oral toxicity (Madsen et al., 2001). No mutagenicity or carcinogenicity was observed with the Ames Test and in a chromosomal aberration assay in vitro using a Chinese hamster fibroblast cell line (Ishidate et al. 1984). Sodium triphosphate was shown to have no reproductive effects with doses up to 238 mg/kg/day (IPCS 1982).
125005-87-0	Diutan	Repeated dose exposures found no effects at up to 1000 mg/kg/day in a 28-day repeat dose oral toxicity study using OECD Test Guideline 407 (US EPA, 2016a).
112-40-3	Dodecane	No effects observed in a study with exposures up to 5000 mg/kg/day of mixed alkanes with lengths of 10 or more carbon atoms, reported in the registration dossier for ECHA REACH program (ECHA, Dodecane)
78330-21-9	Ethoxylated alcohol C11-14	See Alcohol, C-10-14 ethoxylated
68439-45-2	Ethoxylated alcohol C6-12	See Alcohol, C-10-14 ethoxylated
No CASRN	Ethoxylated C11 Alcohol	See Alcohol, C-10-14 ethoxylated
67762-38-3	Fatty acid ester	No effects observed in a study with exposures up to 1000 mg/kg/day, reported in the registration dossier for ECHA REACH program (ECHA, 'Fatty acids, C16-18 and C18-unsatd., Me esters')
61788-91-8	Fatty alkyl amines	Risks associated with fatty acid amines is the presence of nitrosamine contamination. Nitrosamines are known carcinogens with one of the most potent being nitrosodiethanolamine, a liver carcinogen in rats (IARC, 1978).
142-62-1	Hexanoic acid	The only effects observed were marked hyperplasia of the squamous epithelium of the forestomach in all high dose animals, and to a minimal degree, in 3 intermediate dose group animals. The forestomach is not a structure found in humans, making the finds of no toxicological relevance (Potokar, 1983). Moody and Reddy (1977) exposed rats to 2, 4 and 8% hexanoic acid (corresponding to 1000, 2000, 4000 mg/kg/day) in diet for 3 weeks before alterations in body weight gain, liver size, hepatic enzyme activity and hepatic peroxisome proliferation were examined. No effects were observed by hexanoic acid, the authors concluded that the NOAEL was ≥ 4000 mg/kg bw/day.

Table 4 continued... Chemicals without chronic oral toxicity

CASRN	Chemical Name	Notes
7783-06-4	Hydrogen sulfide	Hydrogen sulfide is a common nuisance contaminant in drinking water. The taste and odor threshold in water is estimated to be between 0.05 and 0.1 mg/L (WHO, 2017a). No reliable human or animal studies have been published that have investigated chronic oral exposures (ATSDR, 2006). It is unexpected that it would be difficult for a person to consume a toxic dose of hydrogen sulfide in drinking water (WHO, 2017b); this likely holds for hydrogen sulfide in crops. During final distribution of irrigation waters, there is ample opportunity for the water to oxygenate. Sulfide oxidizes readily in oxygenated waters to either sulfur or sulfate, both with limited toxicity.
No CASRN	Ionic Surfactants	A review of animal toxicity studies looking at chronic oral exposures to a large variety of anionic and cationic surfactants did not indicate increased risk for adverse carcinogenic, chronic systemic, or reproductive outcomes (Madsen et al., 2001).
64741-46-4	Light aliphatic naphtha	In rats treated with mixtures of hydrocarbons, some nephrotoxicity was observed that was related to the alkane components. The kidney effects observed only in male rats are indicative of alpha-2u-globulin nephropathy. These kidney effects are specific to male rats and are not considered to be of biological relevance to humans (Halder et al., 1985).
74-87-3	Methyl Chloride	Methyl chloride is not assessed under IRIS for oral exposure and it is not classifiable as a human carcinogen. In water it is moderately soluble and decomposes to methanol and hydrogen chloride; this dissolution will reduce toxicity. Methanol is addressed in the set of chemicals of interest. Hydrogen chloride in produced water is likely to be found as a very weak solution of hydrochloric acid and likely much less corrosive than human stomach contents. See discussion in section 'Chemicals considered to be non-toxic or generally regarded as safe (GRAS)' (US EPA, 2001).
No CASRN	n-Alkanes	See Dodecane, registration dossier reports toxicologic data for mixed hydrocarbons with length of 10 or more carbons
124-18-5	n-Decane	See Dodecane, registration dossier reports toxicologic data for mixed hydrocarbons with length of 10 or more carbons
3452-07-1	n-Eicosene	No effects observed in a 90-day rat study with exposures up to 1000 mg/kg/day of multiple carbon number isomerized olefins and alkenes with length C20-24; also, no effects observed in 1000 mg/kg/day tetradec-1-ene (ECHA, Icos-1-ene)
544-76-3	n-Hexadecane	See Dodecane, registration dossier reports toxicologic data for mixed hydrocarbons with length of 10 or more carbons
593-45-3	n-Octadecane	See Dodecane, registration dossier reports toxicologic data for mixed hydrocarbons with length of 10 or more carbons

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Table 4 continued... Chemicals without chronic oral toxicity

CASRN	Chemical Name	Notes
629-59-4	n-Tetradecane	See Dodecane, registration dossier reports toxicologic data for mixed hydrocarbons with length of 10 or more carbons
6419-19-8	Nitrilotris (methylene phosphonic acid)	No effects observed in a study with exposures up to 500 mg/kg/day, reported in the registration dossier for ECHA REACH program (ECHA, Nitrilotrimethylenetris(phosphonic acid)).
56919-55-2	Pentadecane, 3-methylene	See Pentadecane, 7-methylene as a read-across compound
115146-98-0	Pentadecane, 5-methylene	See Pentadecane, 7-methylene as a read-across compound
13043-55-5	Pentadecane, 7-methylene	There is little indication of toxicity, only acute toxicity with an LD50 >10g/kg. No other indications of toxicity reported in ECHA REACH dossier (ECHA, Pentadecene, 7-methylene).
9003-05-8	Polyacrylamide	Polymerized acrylamide is non-toxic, unlike its monomer (Klassen and Watkins, 1996).
26100-51-6	Polyactide resin [Polylactic acid]	Polylactic acid (PLA) is insoluble in water, it is used to make biodegradable food and beverage containers and for cosmetic surgery. The L-isomer (PLLA) is biologically inert (Simamora and Chern, 2006). PLA was first used for degradable implants; upon hydrolysis, lactic acid is produced, which is an intermediate carbohydrate metabolite (Szycher et al., 2014).
25322-69-4	Polypropylene glycol	Polyethylene glycols (PEGs) are acutely toxic, with no known chronic effects. The probably lethal oral dose in adult humans is between 1 oz and 1 pint (Laurence, 1977). Using PEGs as a read-across compound, polypropylene glycol likely has similar toxicologic properties.
9002-89-5	Polyvinyl alcohol	Polyvinyl Alcohol (PVA) has been orally administered to mice at doses of up to 2000 mg/kg/d with no evidence of bone marrow or chromosomal damage (TOXNET, 2016); in a rat study, doses of up to 5000 mg/kg/day did not show any effect (Kelly et al., 2003); PVA is not absorbed well in the gastrointestinal tract and does not accumulate in the body when ingested (DeMerlis and Schoneker, 2003).
7646-93-7	Potassium bisulfate	Produces a weak acid with potassium and sulfate ions in water. Potassium is a dietary requirement and sulfate is a common ion in food additives, such as calcium sulfate
1310-58-3	Potassium hydroxide	Potassium hydroxide is a strong base whose main concern to health arises due to its caustic properties, where it will irritate skin and other tissues (TOXNET, 2015b).
68153-60-6	Salt of fatty acid polyamine	See Fatty alkyl amines

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Table 4 continued... Chemicals without chronic oral toxicity

CASRN	Chemical Name	Notes
7631-86-9	Non-crystalline silica [amorphous silica]	The route of exposure of concern for amorphous silica is inhalation. The available data are insufficient to demonstrate an association for an adverse outcome with oral exposure (ATSDR, 2017).
1338-43-8	Sorbitan, mono-(9Z)-9-octadecenoate [Sorbitan oleate]	There are no known human health effects observed with ingestion of sorbitan oleate. In a study where humans were given 6 grams of sorbitan oleate per day for 30 days, no effects were observed (Gosselin et al., 1976)
67784-80-9	Soybean oil, Me ester	See Fatty acid ester
61790-33-8	Tallow alkyl amines	See Fatty alkyl amines
629-59-4	Tetradecane	See Dodecane, registration dossier reports toxicologic data for mixed hydrocarbons with length of 10 or more carbons
7440-32-6	Titanium	Chronic toxicity of titanium and its alloys related to inhalation exposures (Stellman, 1998))
629-50-5	Tridecane	No effects observed in a study with exposures up to 5000 mg/kg/day, reported in the registration dossier for ECHA REACH program.
112-27-6	Triethylene Glycol	No toxicologically relevant local or systemic effects were observed in a rat study with doses of up to 4360 mg/kg/d over 90 days (Van and Ballantyne, 2001). Later studies have also reported a similar lack of relevant local or systemic toxicity (Ballantyne and Snelling, 2007)
13573-18-7	Triphosphoric acid, sodium salt	Polyphosphates have low oral toxicity (Madsen et al., 2001). No mutagenicity or carcinogenicity was observed with the Ames Test and in a chromosomal aberration assay in vitro using a Chinese hamster fibroblast cell line (Ishidate et al. 1984). Sodium triphosphate was shown to have no reproductive effects with doses up to 238 mg/kg/day (IPCS 1982).
No CASRN	Triterpenes	Triterpenes are naturally occurring in plant, animals and fungi. The class of chemicals have been investigated as to their use as a chemotherapeutic agent and thought to have low toxicity to health cells (Chudik et al., 2015). In a study looking at the pharmacokinetics of a triterpenes after ingestion at a dose of 30-60 mg of total triterpenes from <i>Centella asiatica</i> —which mainly contain asiaticoside, madecassoside, asiatic and madecassic acids (Bylka et al., 2013)—no adverse systemic effects were observed (Grimaldi et al, 1990).
1120-21-4	Undecane	No effects observed in a rat study with exposures up to 1000 mg/kg/day, reported in the registration dossier for the ECHA REACH program (ECHA, Undecane).

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Table 4 continued... Chemicals without chronic oral toxicity

CASRN	Chemical Name	Notes
57-13-6	Urea	No effects observed in a study with exposures up to 2250 mg/kg/d in the rat and 6750 mg/kg/d in the mouse (Fleischman et al., 1980). Also classified as GRAS (FDA, SCOGS).

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Table 5: Chemicals with incomplete information related to chronic oral toxicity

CASRN	Chemical	Notes
100-73-2	Acrolein dimer	Acrolein dimer is the polymerized version of acrolein; it has a free aldehyde group. There is some evidence that the polymer is less toxic than the monomers with LD50 of 4920mg/kg and 26mg/kg, respectively. Long-term oral exposure to acrolein, at an amount within the range of human unsaturated aldehyde intake, induces a phenotype of dilated cardiomyopathy in the mouse, i.e., 1mg/kg for 48 days. Human exposure to acrolein may have analogous effects and raise consideration of an environmental, aldehyde-mediated basis for heart failure (Ismahil et al., 2011). The literature suggests that the toxicity for most aldehydes are mediated through similar pathways and similar function groups (LoPachin and Gavin, 2014).
No CASRN	Aromatic Amine	Toxicity of aromatic amines is related to the form. See discussion below.
38011-25-5	Disodium ethylenediaminetetraacetate	Sodium EDTA has been shown in some studies to be cytotoxic, a reproductive toxicant, and to demineralize teeth, bones and organs in animals. However, for these studies, identifying the mg/kg doses is not possible because exposure groups are categorized by percentage of EDTA in food. Other studies reported in the same EDTA assessment report show no toxicity in rats exposed to 375 mg/kg/day for 721 days; no effects in a multigeneration study where rats were exposed up to 250 mg/kg/day; and in a dog study, no effects were seen in exposures up to 250 mg/kg/day (Lanigan and Yamerick 2002).
1415-93-6	Humic acids	There is some evidence that Humic Acid could mechanistically be chronically toxic, as it promotes lipid peroxidation (Ho et al., 2003); damage to vascular endothelial cells (Kihara et al., 2014); and damage to cultured human umbilical endothelial cells (Hseu, 2002). However, there are no studies looking at exposures in humans. Humic acids are naturally occurring and no dosage information is available.
85-01-8	Phenanthrene	There are no reliable human studies assessing chronic oral exposure to phenanthrene. The acute toxicity of phenanthrene has been determined for phenanthrene at 700 mg/kg (Lewis, 2005). It is not assessed under IRIS for oral exposure (US EPA, 1990). It is also not classifiable as to its human carcinogenicity due to a lack of studies (IARC, 2010a). However, a test of human lymphoblast TK6 cells incubated with rat liver S9 (Arochlor) and 9 ug/mL phenanthrene yielded a forward mutation (US EPA, 1990).
19019-43-3	Polycarboxylate salt [Trisodium ethylenediaminetetraacetate]	See Disodium ethylenediaminetetraacetate

Table 5 continued... Chemicals with incomplete information related to chronic oral toxicity

CASRN	Chemical	Notes
91-63-4	Quinaldine	Unable to find studies looking at chronic exposure to quinaldine. LD50 is 1230mg/kg in rats. It has the weakest mutagenicity among methyquinoline, with some indication of mutagenicity in bacterial cultures. Different bacteria studies of genotoxicity report both mutagenic (Dong et al., 1978; Takahashi et al., 1988) and null effects (Bowden et al., 1976). These kinds of bacterial culture studies do not necessarily predict cancer in higher life forms well (Hakura et al., 1999). However, innocuous chemicals rarely give false positives (Priva et al 1991)
NP-SMO3_U1240	Sorbitan ester	There are three main esters of sorbitan (sorbitan monostearate, sorbitan tristearate, and sorbitan monolaurate). Each of these esters of sorbitan are food additives and act as emulsifiers or wetting agents. It is unclear from the entry if the sorbitan used in oil and gas production is the same as that which is used as a food additive. For this reason, it is unclear as to the toxic potential of this oil/gas field additive. For context, sorbitan monostearate is practically non-toxic with a probably human-lethal dose greater than 15 g/kg (Gosselin et al., 1976).
65996-69-2	Steel mill slag	TSCA Definition 2018: The fused substance formed by the action of a flux upon the gangue of the iron-bearing materials charged to a blast furnace and upon the oxidized impurities in the iron produced. Depending upon the particular blast furnace operation, the slag is composed primarily of sulfur and oxides of aluminum, calcium, magnesium, and silicon. Toxicity for steel mill slag will likely be attributable to metals discussed further in other sections of this report. There was no available literature directly assessing toxicity of steel mill slag contamination of waters.
8052-41-3	Stoddard Solvents	In general, ingestion of most petroleum distillates at doses less than 1,000 mg/kg causes little toxicity (Ellenhorn and Barceloux, 1988)
64-02-8	Tetrasodium ethylenediaminetetraacetate	See Disodium ethylenediaminetetraacetate
74-84-0	Polyethylene	For this entry, "Polyethylene" in the list of chemical additives, a query of the CASRN number associated with the entry does not return polyethylene, but instead returns Ethane. Ethane is considered to be physiologically and toxicologically inert. At high concentration, risks are associated with the displacement of oxygen, which results in asphyxiation (Browning and Snyder, 1987). It is also possible that the CASRN is incorrect and this should be polyethylene glycol. Polyethylene glycols (PEGs) are acutely toxic, with no known chronic effects. The probably lethal oral dose in adult humans is between 1 oz and 1 pint (Laurence, 1977). However, PEG 3350 is used as a mild laxative in Miralax™, and other similar over-the-counter laxative products, with a dose of 17 g per day.

Table 6: List of aromatic amines with IARC carcinogenicity classification⁵

Group 1: Carcinogenic to humans	4-Aminobiphenyl Benzidine 4,4'-methylenebis(2-chloroaniline) 2-Naphthylamine ortho-Toluidine
Group 2B: Possibly carcinogenic to humans	Auramine 4-Chloro-ortho-toluidine

⁵ This is the list of aromatic amines evaluated in the IARC monograph. It is unknown at this time which of these are used as additives in oil and gas development

Table 7: List of chemicals with toxicity values ordered from most to least toxic, including their respective NOAEL/LOEL and derived uncertainty factor (UF) associated with the toxicity value, and OECD biodegradation classification.

CASRN	Chemical Name	Notes	Toxicity Value (mg/kg/d)	NOAEL/LOEL (mg/kg/d)*	UF*	OECD Biodeg.
79-06-1	Acrylamide	1 in 100000 cancer risk dose (CalEPA, OEHHA)	0.000002	NA	NA	Readily Biodeg.
53-70-3	Dibenzo(a,h)anthracene	1 in 100000 cancer risk dose (CalEPA, OEHHA)	0.0000024	NA	NA	Poorly Biodeg.
50-32-8	Benzo(a)pyrene	1 in 100000 cancer risk dose (CalEPA, OEHHA)	0.000003	NA	NA	Poorly Biodeg.
119-65-3	Isoquinoline	1 in 100000 cancer risk dose (US EPA, IRIS); quinoline used as a read-across compound	0.000003	NA	NA	Poorly Biodeg.
111-44-4	Bis (2-chloroethyl) ether	1 in 100000 cancer risk dose (CalEPA, OEHHA)	0.000004	NA	NA	Poorly Biodeg.
7440-38-2	Arsenic	1 in 100000 cancer risk dose (US EPA, IRIS)	0.000007	NA	NA	Inorganic
205-99-2	Benzo(b)fluoranthene	1 in 100000 cancer risk dose (CalEPA, OEHHA)	0.000008	NA	NA	Poorly Biodeg.
193-39-5	Indenopyrene	1 in 100000 cancer risk dose (CalEPA, OEHHA)	0.000008	NA	NA	Poorly Biodeg.
56-55-3	Benzo(a)anthracene	1 in 100000 cancer risk dose (CalEPA, OEHHA)	0.000008	NA	NA	Poorly Biodeg.
100-44-7	Benzyl chloride	1 in 100000 cancer risk dose (US EPA, IRIS)	0.00006	NA	NA	Readily Biodeg.
218-01-9	Chrysene	1 in 100000 cancer risk dose (CalEPA, OEHHA)	0.00008	NA	NA	Poorly Biodeg.
91-20-3	Naphthalene	1 in 100000 cancer risk dose (CalEPA, OEHHA)	0.00008	NA	NA	Inherent Biodeg.
123-91-1	1,4 Dioxane	1 in 100000 cancer risk dose (US EPA, IRIS)	0.0001	NA	NA	Non-biodeg.
71-43-2	Benzene	1 in 100000 cancer risk dose (CalEPA, OEHHA)	0.0001	NA	NA	Readily Biodeg.
7440-43-9	Cadmium	MRL (ATSDR)	0.0001	NA	NA	Inorganic
7439-97-6	Mercury	REL (OEHHA)	0.00016	NA	NA	Inorganic
7440-48-4	Cobalt	RfD (US EPA, PPRTV)	0.0003	NA	NA	Inorganic
7440-36-0	Antimony	RfD (US EPA, IRIS)	0.0004	NA	NA	Inorganic
1309-64-4	Antimony trioxide	See Antimony, RfD (US EPA, IRIS).	0.0004	NA	NA	Inorganic
50-00-0	Formaldehyde	1 in 100000 cancer risk dose (CalEPA, OEHHA)	0.00048	NA	NA	Readily Biodeg.
107-02-8	Acrolein	RfD (US EPA, IRIS)	0.0005	NA	NA	Readily Biodeg.

*NA in the NOAEL/LOEL and UF fields indicate that the toxicity value was obtained from a published [normally government agency] source

Table 7 continued... List of chemicals with toxicity values ordered from most to least toxic...

CASRN	Chemical Name	Notes	Toxicity Value (mg/kg/d)	NOAEL/LOAEL (mg/kg/d)*	UF*	OECD Biodeg.
100-41-4	Ethylbenzene	1 in 100000 cancer risk dose (CalEPA, OEHHA)	0.0009	NA	NA	Readily Biodeg.
5064-31-3	Trisodium nitrilotriacetate	1 in 100000 cancer risk dose (CalEPA, OEHHA)	0.001	NA	NA	Readily Biodeg.
7439-92-1	Lead	1 in 100000 cancer risk dose (CalEPA, OEHHA)	0.001	NA	NA	Inorganic
7439-93-2	Lithium	RfD (EPA, PPRTV)	0.002	NA	NA	Inorganic
107-19-7	Propargyl alcohol	RfD (US EPA, IRIS)	0.002	NA	NA	Readily Biodeg.
111-42-2	Diethanolamine	RfD (US EPA, PPRTV)	0.002	NA	NA	Readily Biodeg.
1310-65-2	Lithium hydroxide	See Lithium, RfD (EPA, PPRTV)	0.002	NA	NA	Inorganic
13453-71-9	Lithium chlorate	See Lithium, RfD (EPA, PPRTV)	0.002	NA	NA	Inorganic
13840-33-0	Lithium hypochlorite	See Lithium, RfD (EPA, PPRTV)	0.002	NA	NA	Inorganic
554-13-2	Lithium carbonate	See Lithium, RfD (EPA, PPRTV)	0.002	NA	NA	Inorganic
7440-41-7	Beryllium	RfD (US EPA, Drinking Water Standards and Advisory Tables)	0.002	NA	NA	Inorganic
7447-41-8	Lithium chloride	See Lithium, RfD (EPA, PPRTV)	0.002	NA	NA	Inorganic
7440-61-1	Uranium	RfD (US EPA, IRIS)	0.003	NA	NA	Inorganic
7440-47-3	Chromium	RfD (US EPA, IRIS)	0.003	NA	NA	Inorganic
91-57-6	2-Methylnaphthalene	RfD (US EPA, IRIS)	0.004	NA	NA	Readily Biodeg.
7439-98-7	Molybdenum	RfD (US EPA, IRIS)	0.005	NA	NA	Inorganic
7782-49-2	Selenium	RfD (US EPA, IRIS)	0.005	NA	NA	Inorganic
7440-22-4	Silver	RfD (US EPA, IRIS)	0.005	NA	NA	Inorganic
140-88-5	Ethyl acrylate	RfD (US EPA, PPRTV)	0.005	NA	NA	Readily Biodeg.
26172-55-4	Methylchloroisothiazolinone	A sub-chronic rat study found decreased cumulative body weight gain and decreased feed consumption effects. NOAEL = 19 mg/kg/d (ECHA, 2-methyl-2H-isothiazol-3-one). Additional uncertainty factor of 5 was added due to the small size of the sample.	0.006	19	3100	Inherent Biodeg.

*NA in the NOAEL/LOAEL and UF fields indicate that the toxicity value was obtained from a published [normally government agency] source

Table 7 continued... List of chemicals with toxicity values ordered from most to least toxic...

CASRN	Chemical Name	Notes	Toxicity Value (mg/kg/d)	NOAEL/LOAEL (mg/kg/d)*	UF*	OECD Biodeg.
55566-30-8	Phosphonium, tetrakis (hydroxymethyl)- sulfate (2:1) salt	A sub-chronic rat study found hypoactivity, emaciation, salivation and urogenital staining effects. NOAEL = 4.53 mg/kg/d (ECHA, Tetrakis(hydroxymethyl)phosphonium sulphate(2:1)).	0.007	4.53	620	Inherent Biodeg.
90-12-0	1-Methylnaphthalene	RfD (US EPA, PPRTV)	0.007	NA	NA	Readily Biodeg.
108-67-8	1,3,5-Trimethylbenzene	RfD (US EPA, IRIS)	0.01	NA	NA	Readily Biodeg.
526-73-8	1,2,3-Trimethylbenzene	RfD (US EPA, IRIS)	0.01	NA	NA	Readily Biodeg.
7440-50-8	Copper	MRL (ATSDR)	0.01	NA	NA	Inorganic
7553-56-2	Iodine	MRL (ATSDR)	0.01	NA	NA	Inorganic
7758-99-8	Copper sulfate pentahydrate	MRL (ATSDR)	0.01	NA	NA	Inorganic
95-63-6	1,2,4-Trimethylbenzene	RfD (US EPA, IRIS)	0.01	NA	NA	Readily Biodeg.
7440-02-0	Nickel	REL (CalEPA, OEHHA)	0.01	NA	NA	Inorganic
7786-81-4	Nickel sulfate	REL (CalEPA, OEHHA)	0.01	NA	NA	Inorganic
98-00-0	Furfuryl alcohol	In an unpublished study from 1952, moderate degeneration of hepatocytes and tubular epithelial cells in the renal cortex was observed in rats given doses of 75, 150 or 300 mg/kg body weight (NTP, 1999).	0.01	75	6200	Readily Biodeg.
4719-04-4	Triazinetriethanol	A sub-chronic rat study found reduction in margination of the hepatocyte cytoplasm effects. NOAEL = 10 mg/kg/d (ECHA, 2,2',2''-(hexahydro-1,3,5-triazine-1,3,5-triyl)triethanol).	0.02	10	620	Readily Biodeg.
105-67-9	2,4-Dimethylphenol	RfD (US EPA, IRIS)	0.02	NA	NA	Readily Biodeg.
108-90-7	Chlorobenzene	RfD (US EPA, IRIS)	0.02	NA	NA	Poorly Biodeg.
120-12-7	Anthracene	RfD (US EPA, Drinking Water Standards and Advisory Tables)	0.02	NA	NA	Poorly Biodeg.
64742-53-6	Distillates, hydrotreated light naphthenic	A sub-chronic rat study found hematologic effects. LOAEL = 125 mg/kg/d (ECHA, Distillates (petroleum), hydrotreated light naphthenic). Additional uncertainty factor of 10 was added due to the small size of the sample and methodologic issues.	0.02	125	6200	No data, as mixture

*NA in the NOAEL/LOAEL and UF fields indicate that the toxicity value was obtained from a published [normally government agency] source

Table 7 continued... List of chemicals with toxicity values ordered from most to least toxic...

CASRN	Chemical Name	Notes	Toxicity Value (mg/kg/d)	NOAEL/LOAEL (mg/kg/d)*	UF*	OECD Biodeg.
64742-55-8	Paraffinic petroleum distillate, hydrotreated light	A sub-chronic rat study found hematologic effects. LOAEL = 125 mg/kg/d (ECHA, Distillates (petroleum), hydrotreated light paraffinic). Additional uncertainty factor of 10 was added due to the small size of the sample and methodologic issues.	0.02	125	6200	Inherent Biodeg.
129-00-0	Pyrene	RfD (US EPA, IRIS)	0.03	NA	NA	Poorly Biodeg.
64742-95-6	Solvent naphtha, petroleum, light arom.	RfD (US EPA, PPRTV)	0.03	NA	NA	Poorly Biodeg.
25265-78-5	Benzene, tetrapropylene-	A sub-chronic rat study found minimal/mild mineral deposition and vacuolation of tubular epithelium in corticomedullary junction of the kidney effects. NOAEL = 24 mg/kg/d (ECHA, Benzene, mono-C11-C13-branched alkyl derivatives).	0.04	24	620	Poorly Biodeg.
123-31-9	Hydroquinone	RfD (US EPA, PPRTV)	0.04	NA	NA	Inherent Biodeg.
141-43-5	Monoethanolamine	NSF International evaluated the noncancer oral toxicity data for ethanolamine and calculated a reference dose (RfD) of 0.04 mg/kg-day. The RfD was based on a NOAEL of 120 mg/kg-day for maternal toxicity observed in pregnant rats that received ethanolamine via gavage (Hellwig and Liberacki, 1997).	0.04	NA	NA	Readily Biodeg.
29868-05-1	Alkanolamine phosphate	See Monoethanolamine	0.04	NA	NA	Poorly Biodeg.
206-44-0	Fluoranthene	RfD (US EPA, IRIS)	0.04	NA	NA	Poorly Biodeg.
86-73-7	Fluorene	RfD (US EPA, IRIS)	0.04	NA	NA	Readily Biodeg.
16984-48-8	Fluoride	MRL (ATSDR)	0.05	NA	NA	Inorganic
1341-49-7	Ammonium bifluoride	MRL (ATSDR) as fluoride	0.05	NA	NA	Readily Biodeg.
7664-39-3	Hydrofluoric acid	MRL (ATSDR) as fluoride	0.05	NA	NA	Inorganic
95-48-7	o-Cresol	RfD (US EPA, IRIS)	0.05	NA	NA	Readily Biodeg.
208-96-8	Acenaphthylene	RfD (US EPA, PPRTV)	0.06	NA	NA	Inherent Biodeg.
83-32-9	Acenaphthene	RfD (US EPA, IRIS)	0.06	NA	NA	No data
111-76-2	2-Butoxyethanol	MRL (ATSDR)	0.07	NA	NA	Readily Biodeg.

*NA in the NOAEL/LOAEL and UF fields indicate that the toxicity value was obtained from a published [normally government agency] source

Table 7 continued... List of chemicals with toxicity values ordered from most to least toxic...

CASRN	Chemical Name	Notes	Toxicity Value (mg/kg/d)	NOAEL/LOAEL (mg/kg/d)*	UF*	OECD Biodeg.
115-19-5	2-methyl-3-Butyn-2-ol	A sub-chronic rat study found systemic toxicity manifested on kidney, as well as reproductive organs epididymis, testis, and ovary effects. NOAEL = 45 mg/kg/d (ECHA, 2-methylbut-3-yn-2-ol).	0.073	45	620	Poorly Biodeg.
108-88-3	Toluene	RfD (US EPA, IRIS)	0.08	NA	NA	Readily Biodeg.
68648-87-3	Benzene, c10-c16 alkyl derivatives	In a rat study looking at reproductive effects, a NOAEL of 5mg/kg/day was identified for exposure during gestation. Outcomes were depressed weight gains in adults, smaller litters, and fewer live pups; decreased pup survival and lower pup weights were also found at some higher dosing levels (Robinson and Schroeder, 1992).	0.08	5	62	Readily Biodeg.
127087-87-0	Nonylphenol polyethylene glycol ether	A sub-chronic rat study found developmental and reproductive effects. NOAEL = 50 mg/kg/d (ECHA, 4-Nonylphenol, branched, ethoxylated).	0.081	50	620	Poorly Biodeg.
No CASRN	Nonylphenol ethoxylates	This is a branched ethoxylated nonylphenol. See Nonylphenol polyethylene glycol ether	0.081	50	620	Poorly Biodeg.
68412-54-4	Oxyalkylated alkylphenol	This is a branched ethoxylated nonylphenol. See Nonylphenol polyethylene glycol ether	0.081	50	620	Poorly Biodeg.
14797-65-0	Nitrite	RfD (US EPA, IRIS)	0.1	NA	NA	Inorganic
7440-62-2	Vanadium	MRL (ATSDR)	0.1	NA	NA	Inorganic
104-76-7	2-Ethylhexan-1-ol	NSF International evaluated the noncancer oral toxicity data for 2-ethylhexanol (2-EH) and calculated a reference dose (RfD) of 0.1 mg/kg-day. The RfD was based on a NOAEL of 36 mg/kg-day observed in a chronic gavage study in Fischer rats (Astill et al., 1996), in which there was a reduction in mean body weight of 10% or greater, and altered organ weights compared to concurrent controls. NSF International applied a composite uncertainty factor of 300 (10 each for inter- and intraspecies extrapolation and 3 for database deficiencies).	0.1	NA	NA	Inherent Biodeg.
106-44-5	p-Cresol	MRL (ATSDR)	0.1	NA	NA	Readily Biodeg.
111-30-8	Glutaraldehyde	MRL (ATSDR)	0.1	NA	NA	Readily Biodeg.
2634-33-5	1,2 Benzisothiazol-3(2H)-one	A sub-chronic rat study found thickening of stomach lining tissue and decreased body weight effects. NOAEL = 69 mg/kg/d (ECHA, 1,2-benzisothiazol-3(2H)-one).	0.1	69	620	Readily Biodeg.
59-50-7	p-Chloro-m-cresol	RfD (US EPA, PPRTV)	0.1	NA	NA	Readily Biodeg.

*NA in the NOAEL/LOAEL and UF fields indicate that the toxicity value was obtained from a published [normally government agency] source

Table 7 continued... List of chemicals with toxicity values ordered from most to least toxic...

CASRN	Chemical Name	Notes	Toxicity Value (mg/kg/d)	NOAEL/LOAEL (mg/kg/d)*	UF*	OECD Biodeg.
5989-27-5	d-Limonene	d-Limonene is a major component in the oil of citrus fruit peels. IPCS has evaluated the noncancer oral toxicity data for d-Limonene, and derived a tolerable daily intake (TDI) of 0.1 mg/kg-day based on a NOAEL of 10 mg/kg-day for increased relative liver weight observed in rats in a subchronic oral gavage study (Webb et al., 1989) and a composite uncertainty factor of 100 (10 each for intraspecies and interspecies differences).	0.1	NA	NA	Readily Biodeg.
8028-48-6	Orange terpenes	See d-Limonene as read-across assessment. This is an unspecified mixture of compounds derived from citrus. Many of the compounds are reported as citrus terpenes or d-Limonene.	0.1	NA	NA	Readily Biodeg.
84-74-2	di-n-Butylphthalate	RfD (US EPA, IRIS)	0.1	NA	NA	Readily Biodeg.
98-82-8	Cumene	RfD (US EPA, IRIS)	0.1	NA	NA	Readily Biodeg.
68439-57-6	Sodium C14-16 olefin sulfonate	A sub-chronic rat study found degeneration and atrophy of the olfactory epithelium and degeneration and regeneration in the respiratory epithelium effects. NOAEL = 70 mg/kg/d (ECHA, Sulfonic acids, C14-16 (even numbered)-alkane hydroxy and C14-16 (even numbered)-alkene, sodium salts).	0.11	70	620	Readily Biodeg.
140-01-2	Pentasodium diethylenetriamine pentaacetate	A sub-chronic rat study found body weight and histopathological changes of the urinary tract with corroborating results of the urinalyses effects. NOAEL = 75 mg/kg/d (ECHA, Pentasodium (carboxylatomethyl)iminobis(ethylenitrilo)tetraacetate).	0.12	75	620	Readily Biodeg.
64742-94-5	Heavy aromatic naphtha	A sub-chronic rat study found clinical pathology, body weight, organ weights, and irritation effects. LOAEL = 750 mg/kg/d (ECHA, Solvent naphtha (petroleum), heavy arom.). Additional uncertainty factor of 10 was added due to the small size of the sample and methodologic issues.	0.12	750	6200	Readily Biodeg.
7783-18-8	Inorganic sulfur compound [Ammonium thiosulfate]	A sub-chronic rat study found occult blood in the feces and changes in gastric morphology effects. NOAEL = 72 mg/kg/d (ECHA, Ammonium thiosulphate).	0.12	72	620	Inorganic
9003-01-4	Polyacrylic acid	A sub-chronic rat study found decreased food and water intakes, and decreased body and organ weights effects. NOAEL = 83 mg/kg/d (ECHA, 2-Propenoic acid, homopolymer).	0.13	83	620	Readily Biodeg.
7439-96-5	Manganese	RfD (US EPA, IRIS)	0.14	NA	NA	Inorganic

*NA in the NOAEL/LOAEL and UF fields indicate that the toxicity value was obtained from a published [normally government agency] source

Table 7 continued... List of chemicals with toxicity values ordered from most to least toxic...

CASRN	Chemical Name	Notes	Toxicity Value (mg/kg/d)	NOAEL/LOAEL (mg/kg/d)*	UF*	OECD Biodeg.
7446-09-5	Sulfur dioxide	MADL (CalEPA, OEHHA)	0.142	NA	NA	Inorganic
75-12-7	Formamide	A chronic mouse study found reduced body weight (~25%), erythron changes, and histopathological changes (degeneration of the germinal epithelium) in the testes and in the epididymis effects. NOAEL = 20 mg/kg/d (ECHA, Formamide).	0.16	20	123	Readily Biodeg.
7775-09-9	Sodium Chlorate	A sub-chronic rat study found adrenal and hematological effects. NOAEL = 100 mg/kg/d (ECHA, Sodium chlorate).	0.161	100	620	Inorganic
61790-41-8	Quaternary ammonium compound	A sub-chronic rat study found higher incidence of haemosiderin accumulation in the kidney effects. NOAEL = 113 mg/kg/d (ECHA, Quaternary ammonium compounds, trimethylsoya alkyl, chlorides).	0.18	113	620	Poorly Biodeg.
2893-78-9	Sodium dichloroisocyanurate	A sub-chronic rat study found labored breathing, emaciation, accumulation of yellow material in the anogenital region, decreased activity and death effects. NOAEL = 115 mg/kg/d (ECHA, Troclosene sodium).	0.185	115	620	Poorly Biodeg.
No CASRN	Severely hydrotreated paraffinic	See Solvent dewaxed heavy paraffinic	0.2	NA	NA	Inherent Biodeg.
7440-42-8	Boron	Rfd (US EPA, IRIS)	0.2	NA	NA	Inorganic
107-22-2	Glyoxal	IPCS has evaluated the noncancer oral toxicity data for glyoxal, and derived a tolerable daily intake (TDI) of 0.2 mg/kg-day based on a NOAEL of 100 mg/kg-day for a dose-related decrease of water and food consumption and body weight observed in a 28-day rat drinking water study (Societe Francaise Hoechst, 1987). IPCS applied a total uncertainty factor of 500 (10 each for inter- and intraspecies differences and 5 for less-than-lifetime exposure).	0.2	NA	NA	Readily Biodeg.
108-91-8	Cyclohexylamine	Rfd (US EPA, IRIS)	0.2	NA	NA	Readily Biodeg.
12179-04-3	Sodium tetraborate pentahydrate	MRL (ATSDR) as boron	0.2	NA	NA	Inorganic

*NA in the NOAEL/LOAEL and UF fields indicate that the toxicity value was obtained from a published [normally government agency] source

Table 7 continued... List of chemicals with toxicity values ordered from most to least toxic...

CASRN	Chemical Name	Notes	Toxicity Value (mg/kg/d)	NOAEL/LOAEL (mg/kg/d)*	UF*	OECD Biodeg.
123-38-6	Propionaldehyde	The EPA has identified that there are no directly applicable human or animal data available to make a determination as to the oral chronic toxicity of propionaldehyde (US EPA, 2008). The most similar compound to propionaldehyde is acetaldehyde, an identified human carcinogen by IARC (IARC, 2010b). Acetaldehyde is a product of ethanol metabolism and is presumed to be a likely agent responsible for the carcinogenicity of drinking alcoholic beverages (Brooks and Theruvathu, 2005)). It is postulated that the carcinogenic toxicity of acetaldehyde is related to it forming reactive DNA adducts that eventually block DNA synthesis and induce DNA damage (Brooks and Theruvathu, 2005; Mizumoto et al., 2017). Given propionaldehyde's similar structure to acetaldehyde, i.e., propionaldehyde's carbon chain is just one carbon atom longer, it will likely form a similarly reactive DNA adduct capable of causing similar DNA damage. Acetaldehyde has been quantitatively evaluated for carcinogenicity by OEHHA with a cancer slope factor of 0.001 per mg/kg/day, but only for the inhalation route. Evidence for the oral route of exposure is not sufficient to make that determination. It is known that as saturated aldehydes get longer, their toxicity decreases (Gosselin et al., 1984), which means that propionaldehyde is less toxic than acetaldehyde. In the context of the use of produced water for irrigation, acetaldehyde is evaluated here for non-cancer outcomes related to oral exposure, based on the available animal data. As the evidence suggests that propionaldehyde is less toxic than acetaldehyde, the surrogate RfD for the latter has been applied to propionaldehyde to provide an informed health protective value.	0.2	NA	NA	Readily Biodeg.
124-68-5	2-Amino-2-methylpropanol	A chronic rat study found adverse hepatic systemic effects. NOAEL = 11 mg/kg/d (ECHA, 2-Amino-2-methylpropanol).	0.2	11	62	Readily Biodeg.
1330-20-7	Xylene	RfD (US EPA, IRIS)	0.2	NA	NA	Readily Biodeg.
27176-87-0	Branched DDBSA	A sub-chronic rat study found squamous cell hyperplasia of stomach effects. NOAEL = 100 mg/kg/d (ECHA, Dodecylbenzenesulphonic acid).	0.2	100	620	Readily Biodeg.
7440-39-3	Barium	MRL (ATSDR)	0.2	NA	NA	Inorganic
75-07-0	Acetaldehyde	A sub-chronic rat study found gastrointestinal hyperkeratosis effects. NOAEL = 125 mg/kg/d (ECHA, Acetaldehyde).	0.2	125	620	Readily Biodeg.

*NA in the NOAEL/LOAEL and UF fields indicate that the toxicity value was obtained from a published [normally government agency] source

Table 7 continued... List of chemicals with toxicity values ordered from most to least toxic...

CASRN	Chemical Name	Notes	Toxicity Value (mg/kg/d)	NOAEL/LOAEL (mg/kg/d)*	UF*	OECD Biodeg.
7727-43-7	Barite	See Barium, MRL (ATSDR)	0.2	NA	NA	Inorganic
79-10-7	Acrylic Acid	RfD (US EPA, PPRTV)	0.2	NA	NA	Readily Biodeg.
No CASRN	Solvent dewaxed heavy paraffinic	Using "Distillates (petroleum), hydrotreated heavy paraffinic" CAS 64742-54-7: Subchronic rat study LOAEL 125mg/kg/day hematological effects observed. (ECHA, Distillates (petroleum), hydrotreated heavy paraffinic)	0.202	125	620	Inherent Biodeg.
108-93-0	Cyclohexanol	A sub-chronic rat study found increase in total cholesterol, total protein and globulins in both sexes, and an increase in platelets in the females, NOAEL = 143 mg/kg/d (ECHA, Cyclohexanol).	0.23	143	620	Readily Biodeg.
79-14-1	Glycolic acid	A sub-chronic rat study found renal oxalate crystal nephropathy effects. NOAEL = 150 mg/kg/d (ECHA, Glycolic acid).	0.24	150	620	Readily Biodeg.
2836-32-0	Sodium glycolate	Sodium glycolate is the sodium salt of glycolic acid, also known as hydroxyacetic acid. In a rat study where glycolic acid was orally administered for 90 day at 0, 150,300, and 600 mg/kg/day, systemic effects were observed; the NOAEL = 150 mg/kg/day. Glycolic acid is naturally occurring in some vegetables, i.e., pineapple, tomatoes, and papaya (TOXNET, 2014). It is metabolized to oxalic acid like ethylene glycol, which is where its systemic toxicity likely arises.	0.242	150	620	Readily Biodeg.
7440-31-5	Tin	MRL (ATSDR)	0.3	NA	NA	Inorganic
108-95-2	Phenol	RfD (US EPA, IRIS)	0.3	NA	NA	Readily Biodeg.
110-54-3	Hexane	RfD (US EPA, PPRTV) for n-Hexane	0.3	NA	NA	Readily Biodeg.
111-46-6	Diethylene glycol	Snelling et al.(2017) used long term animal studies to derive a human equivalent reference dose of 0.3 mg/kg/d.	0.3	NA	NA	Readily Biodeg.
128-37-0	Butylhydroxytoluene	RfD (US EPA, PPRTV)	0.3	NA	NA	Inherent Biodeg.
7440-66-6	Zinc	RfD (US EPA, IRIS)	0.3	NA	NA	Inorganic
7646-85-7	Zinc chloride	as Zinc, RfD (US EPA, IRIS)	0.3	NA	NA	Inorganic
8008-20-6	Kerosene	MRL (ATSDR)	0.3	NA	NA	Inherent Biodeg.
126-97-6	Ethanolamine thioglycolate	A chronic rat study found reproductive effects. NOAEL = 20 mg/kg/d (ECHA, 2-hydroxyethyl)ammonium mercaptoacetate).	0.32	20	62	Poorly Biodeg.

*NA in the NOAEL/LOAEL and UF fields indicate that the toxicity value was obtained from a published [normally government agency] source

Table 7 continued... List of chemicals with toxicity values ordered from most to least toxic...

CASRN	Chemical Name	Notes	Toxicity Value (mg/kg/d)	NOAEL/LOAEL (mg/kg/d)*	UF*	OECD Biodeg.
13598-36-2	Phosphonic acid	A sub-chronic rat study found labored respiration, rales, gasping, piloerection, chromodacryorrhoea of the snout, lethargy, hunched posture, salivation, hypothermia and lean appearance effects. NOAEL = 250 mg/kg/d (ECHA, Phosphonic acid).	0.403	250	620	Readily Biodeg.
68424-85-1	Alkyl dimethylbenzyl ammonium chloride	Rfd (US EPA, HHBP)	0.44	NA	NA	Readily Biodeg.
68081-81-2	Alkyl benzenesulfonate	Read-across assessment; see Benzenesulfonic acid, C10-16-alkyl derivs	0.5	NA	NA	Readily Biodeg.
68308-87-2	Cottonseed, flour	Cottonseed flour contains gossypol, which is a liver, erythrocyte, and male reproductive toxicant; these are related to acute exposure and generally reversible once exposure has ended. Work had been done to test gossypol as a male contraceptive, however this work was stopped because in some cases fertility didn't return once gossypol was no longer being taken (Coutinho, 2002). In the case of male fertility, the contraceptive action of gossypol appears to be reversible at a daily dose of 5 mg/kg/day (Gu et al., 2000). GSI has applied a factor of 10 to account for susceptible populations	0.5	5	10	No data on gossypol
68584-22-5	Benzenesulfonic acid, C10-16-alkyl derivs	Rfd (US EPA, Human Benchmark for Pesticides)	0.5	NA	NA	Poorly Biodeg.
68584-27-0	Benzenesulfonic acid, C10-16-alkyl derivs., potassium salts	Rfd (US EPA, Human Benchmark for Pesticides)	0.5	NA	NA	Poorly Biodeg.
68855-24-3	C14-30 Alkyl Derivatives [Benzenesulfonic acid, mono-C10-16-alkyl derivs., ammonium salts]	This is Benzenesulfonic acid, mono-C10-16-alkyl derivs., ammonium salt. Read across from Benzenesulfonic acid, C10-16-alkyl derivs., potassium salts	0.5	NA	NA	Poorly Biodeg.
68910-31-6	Ammonium alkylaryl sulfonates	This is Benzenesulfonic acid, mono-C10-16-alkyl derivs., ammonium salt. Read across from Benzenesulfonic acid, C10-16-alkyl derivs., potassium salts	0.5	NA	NA	Poorly Biodeg.
68910-32-7	Alkylaryl sulfonates	This is Benzenesulfonic acid, mono-C10-16-alkyl derivs., compds. with ethanolamine. Ethanolamine has less toxicity than the benzosulfonic acid. Read-across assessment, Benzenesulfonic acid, C10-16-alkyl derivs	0.5	NA	NA	Poorly Biodeg.

*NA in the NOAEL/LOAEL and UF fields indicate that the toxicity value was obtained from a published [normally government agency] source

Table 7 continued... List of chemicals with toxicity values ordered from most to least toxic...

CASRN	Chemical Name	Notes	Toxicity Value (mg/kg/d)	NOAEL/LOAEL (mg/kg/d)*	UF*	OECD Biodeg.
7722-84-1	Hydrogen peroxide	NSF International has evaluated the noncancer oral toxicity data for hydrogen peroxide and derived a reference dose (RfD) of 0.5 mg/kg-day based on a BMDL05 of 49 mg/kg-day estimated from data on duodenal hyperplasia observed in catalase-deficient mice following subchronic drinking water exposure (Weiner et al., 2000). NSF International applied an uncertainty factor of 100 (10 for intraspecies variability and 3 each for interspecies variability and database deficiencies).	0.5	NA	NA	Inorganic
79-21-0	Peracetic acid	A chronic rat study found developmental related (in pups) dose-related increase in the severity of fetal liver damage. This was observed and characterized by loosening or unrecognizable structure of liver parenchyma, degeneration to necrosis of the nuclei, atypical mitosis, lysis of hepatic cells, partly large blood islands with cell detritus and pyknotic nuclei effects. NOAEL = 30 mg/kg/d (ECHA, Peracetic acid).	0.5	30	62	Readily Biodeg.
90218-35-2	Alkylarylsulfonate amine salt	This is also known as benzenesulfonic acid, C10-16-alkyl derives., compds. with 2-propanamine. Read-across assessment, Benzenesulfonic acid, C10-16-alkyl derivs. The chronic oral toxicity of 2-propanamine is unclear. This represents the best-known toxicity of this compound.	0.5	NA	NA	Poorly Biodeg.
2809-21-4	Hydroxyethylidenediphosphonic acid	A chronic rat study found hematologic and systemic effects. NOAEL = 34 mg/kg/d (ECHA, Etidronic acid).	0.55	34	62	Poorly Biodeg.
7440-24-6	Strontium	RfD (US EPA, IRIS)	0.6	NA	NA	Inorganic
78-93-3	2-Butanone	RfD (US EPA, IRIS)	0.6	NA	NA	Readily Biodeg.
7439-89-6	Iron	RfD (US EPA, PPRTV)	0.7	NA	NA	Inorganic
141-78-6	Ethyl acetate	RfD (US EPA, PPRTV)	0.7	NA	NA	Readily Biodeg.
17375-41-6	Ferrous sulfate, monohydrate	RfD (EPA, PPRTV) for iron in iron compounds	0.7	NA	NA	Inorganic
107-21-1	Ethylene glycol	MRL (ATSDR)	0.8	NA	NA	Readily Biodeg.
8002-09-3	Pine oil	Maternal and developmental effects observed in a rat study of dams exposed to pine oil during gestation. NOAEL = 50 mg/kg/day. (HAZMAP, Pine Oil)	0.81	50	62	Inherent Biodeg.

*NA in the NOAEL/LOAEL and UF fields indicate that the toxicity value was obtained from a published [normally government agency] source

Table 7 continued... List of chemicals with toxicity values ordered from most to least toxic...

CASRN	Chemical Name	Notes	Toxicity Value (mg/kg/d)	NOAEL/LOAEL (mg/kg/d)*	UF*	OECD Biodeg.
68439-70-3	Alkyl amine	A chronic rat study found adverse minor behavioral, increased liver enzymes, and gastrointestinal irritation effects. NOAEL = 50 mg/kg/d (ECHA, Amines, C12-16-alkyldimethyl).	0.81	50	62	Poorly Biodeg.
69011-36-5	Poly(oxy-1,2-ethanediyl), a-tridecyl-w-hydroxy-branched	A chronic rat study found hematologic effects. NOAEL = 50 mg/kg/d (ECHA, Isotridecanol, ethoxylated).	0.81	50	62	Poorly Biodeg.
67-64-1	Acetone	RfD (US EPA, IRIS)	0.9	NA	NA	Readily Biodeg.
7726-95-6	Bromine (Br)	In 1966, a FAO/WHO meeting on pesticide residue recommended an acceptable daily intake (ADI) for humans of 0–1 mg/kg body weight bromide, based on a minimum pharmacologically effective dosage in humans of approximately 600 mg of bromide ion. A more recent meeting of the group in 1988 reaffirmed the ADI of 0–1 mg/kg body weight (WHO, 2009).	1	NA	NA	Inorganic
1327-41-9	Aluminum chlorohydrate	Read-across assessment; see Aluminum.	1	NA	NA	Inorganic
1344-28-1	Aluminium oxide	RfD (US EPA, PPRTV)	1	NA	NA	Inorganic
7429-90-5	Aluminum	RfD (US EPA, PPRTV)	1	NA	NA	Inorganic
7446-70-0	Aluminum chloride	Read-across assessment; see Aluminum.	1	NA	NA	Inorganic
110-85-0	Piperazine	A sub-chronic rat study found decreases in body weight gain effects. NOAEL = 627 mg/kg/d (ECHA, Piperazine).	1.04	627	620	Readily Biodeg.
10192-30-0	Ammonium bisulfate	A chronic rat study found occult blood in the faeces and changes in gastric morphology effects. NOAEL = 72 mg/kg/d (ECHA, Ammonium hydrogensulphite).	1.2	72	62	Inorganic
577-11-7	Diethyl sulfosuccinate sodium salt	A sub-chronic rat study found minor hematologic effects. NOAEL = 750 mg/kg/d (ECHA, Docusate sodium).	1.16	750	620	Inherent Biodeg.
64742-47-8	Hydrotreated Light Petroleum Distillate	A sub-chronic rat study found clinical pathology, body weight, organ weight effects. NOAEL = 750 mg/kg/d (ECHA, Distillates (petroleum), hydrotreated light).	1.16	750	620	Readily Biodeg.

*NA in the NOAEL/LOAEL and UF fields indicate that the toxicity value was obtained from a published [normally government agency] source

Table 7 continued... List of chemicals with toxicity values ordered from most to least toxic...

CASRN	Chemical Name	Notes	Toxicity Value (mg/kg/d)	NOAEL/LOAEL (mg/kg/d)*	UF*	OECD Biodeg.
7631-90-5	Sodium bisulfite	A chronic rat study found occult blood in the faeces and changes in gastric morphology effects. NOAEL = 72 mg/kg/d (ECHA, Sodium hydrogensulfite).	1.2	72	62	Inorganic
14797-55-8	Nitrate	RfD (US EPA, IRIS)	1.6	NA	NA	Inorganic
34590-94-8	Dipropylene glycol monomethyl ether	A sub-chronic rat study found increased liver weight and centrilobular hypertrophy of the liver effects. NOAEL = 1000 mg/kg/d (ECHA, (2-methoxymethylethoxy)propanol).	1.61	1000	620	Inherent Biodeg.
97722-02-6	Glycerides, tall oil mono-, di, and tri	A sub-chronic rat study found clinical signs, functional observations, body weights, food consumption, clinical pathology, macroscopy, organ weights, and histopathology effects. NOAEL = 1000 mg/kg/d (ECHA, Glycerides, tall-oil mono-, di-, and tri-).	1.61	1000	620	Readily Biodeg.
67-56-1	Methanol	RfD (US EPA, IRIS)	2	NA	NA	Readily Biodeg.
67-63-0	Isopropanol	RfD (US EPA, PPRTV)	2	NA	NA	Inorganic
8012-95-1	Mineral Oil	RfD (US EPA, PPRTV)	3	NA	NA	Readily Biodeg.
65-85-0	Benzoic acid	RfD (US EPA, IRIS)	4	NA	NA	Readily Biodeg.
7783-20-2	Ammonium sulfate	A chronic rat study found increased kidney and liver weight; decreased absolute spleen weight effects. NOAEL = 256 mg/kg/d (ECHA, Ammonium sulphate).	4.1	256	62	Inorganic
25322-68-3	Polyethylene oxide	A sub-chronic rat study found changes in liver and kidney weight effects. NOAEL = 8000 mg/kg/d (ECHA, Poly(oxy-1,2-ethanediyl), α -hydro- ω -hydroxy- Ethane-1,2-diol, ethoxylated).	12.9	8000	620	Readily Biodeg.
57-55-6	Propylene glycol	RfD (US EPA, PPRTV)	20	NA	NA	Readily Biodeg.
7664-38-2	Phosphoric acid	RfD (US EPA, PPRTV)	48.6	NA	NA	Inorganic
7785-84-4	Sodium trimetaphosphate	RfD (US EPA, PPRTV)	49	NA	NA	Inorganic

*NA in the NOAEL/LOAEL and UF fields indicate that the toxicity value was obtained from a published [normally government agency] source

Table 7 continued... List of chemicals with toxicity values ordered from most to least toxic...

CASRN	Chemical Name	Notes	Toxicity Value (mg/kg/d)	NOAEL/LOAEL (mg/kg/d)	UF	OECD Biodeg.
143-07-7	Dodecanoic acid	NSF International has evaluated the noncancer oral toxicity data for dodecanedioic acid and calculated a reference dose (RfD) of 70 mg/kg-day based on a NOAEL of 74 mg/kg-day from a human clinical study (Passi et al., 1983). No critical effect was identified in humans or laboratory animals over the tested dose ranges (Du Pont, 1992 - unpublished, as reported in OECD/SIDS, 1996). NSF International used a composite uncertainty factor of 1, since sufficient data to fulfill all areas of uncertainty were identified.	70	74	1	Readily Biodeg.

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**APPENDIX A: LIST OF CHEMICALS THOUGHT TO NATURALLY OCCURING IN
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Appendix Table A: List of chemicals thought to be naturally occurring in produced water

CASRN	Chemical Name	Source
90-12-0	1-Methylnaphthalene	Hum et al., 2006
78-93-3	2-Butanone	Veil et al., 2004
91-57-6	2-Methylnaphthalene	Hum et al., 2006
105-67-9	2,4-Dimethylphenol	Veil et al., 2004
83-32-9	Acenaphthene	Manfra et al., 2010; OGP, 2002; OGP, 2005
208-96-8	Acenaphthylene	Manfra et al., 2010; OGP, 2002; OGP, 2005
7429-90-5	Aluminum	Guerra et al., 2011
7664-41-7	Ammonia	Liske and Leong, 2006
120-12-7	Anthracene	Manfra et al., 2010; OGP, 2002; OGP, 2005
7440-36-0	Antimony	Guerra et al., 2011
7440-38-2	Arsenic	Martel-Valles et al., 2013; OGP, 2005
7440-39-3	Barium	Veil et al., 2004; OGP, 2005; Dorea et al., 2006
71-43-2	Benzene	Manfra et al., 2010; OGP, 2002; OGP, 2005
56-55-3	Benzo(a)anthracene	Manfra et al., 2010; OGP, 2002; OGP, 2005
50-32-8	Benzo(a)pyrene	Veil et al., 2004; OGP, 2002; OGP, 2005
205-99-2	Benzo(b)fluoranthene	Manfra et al., 2010; OGP, 2002; OGP, 2005
191-24-2	Benzo(ghi)perylene	Hum et al., 2006; OGP, 2002; OGP, 2005
65-85-0	Benzoic acid	Veil et al., 2004
7440-41-7	Beryllium	Guerra et al., 2011
111-44-4	Bis (2-chloroethyl) ether	Hum et al., 2006
7440-42-8	Boron	Guerra et al., 2011
7726-95-6	Bromine (Br)	Guerra et al., 2011
106-97-8	Butane	Hum et al., 2006
128-37-0	Butylhydroxytoluene	Hum et al., 2006
7440-43-9	Cadmium	Manfra et al., 2010; OGP, 2005
7440-70-2	Calcium	Veil et al., 2004; Dorea et al., 2006
124-38-9	Carbon dioxide	Martel-Valles et al., 2016
No CASRN	Carbonate	Martel-Valles et al., 2013; OGP, 2005; Dorea et al., 2006
16887-00-6	Chloride	OGP, 2002; OGP, 2005; Dorea et al., 2006
108-90-7	Chlorobenzene	Veil et al., 2004
7440-47-3	Chromium	Manfra et al., 2010; OGP, 2005;
218-01-9	Chrysene	Manfra et al., 2010; OGP, 2002; OGP, 2005
7440-48-4	Cobalt	Guerra et al., 2011
7440-50-8	Copper	Guerra et al., 2011; OGP, 2005
84-74-2	di-n-Butylphthalate	Veil et al., 2004
53-70-3	Dibenzo(a,h)anthracene	Manfra et al., 2010; OGP, 2002; OGP, 2005
111-46-6	Diethylene glycol	Manfra et al., 2010
100-41-4	Ethylbenzene	Manfra et al., 2010; OGP, 2002; OGP, 2005
206-44-0	Fluoranthene	Manfra et al., 2010; OGP, 2002; OGP, 2005
86-73-7	Fluorene	Manfra et al., 2010; OGP, 2002; OGP, 2005
16984-48-8	Fluoride	Guerra et al., 2011
110-54-3	Hexane	Hum et al., 2006
142-62-1	Hexanoic acid	Hum et al., 2006
7783-06-4	Hydrogen sulfide	Liske and Leong, 2006
193-39-5	Indenopyrene	Manfra et al., 2010; OGP, 2002; OGP, 2005

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Appendix Table A continued... List of chemicals thought to be naturally occurring in produced water

CASRN	Chemical Name	Source
7439-89-6	Iron	Guerra et al., 2011; OGP, 2005
7439-92-1	Lead	Martel-Valles et al., 2013; OGP, 2005
7439-93-2	Lithium	Guerra et al., 2011
7439-95-4	Magnesium	Guerra et al., 2011
7439-96-5	Manganese	Guerra et al., 2011
7439-97-6	Mercury	Manfra et al., 2010; OGP, 2005
7439-98-7	Molybdenum	Guerra et al., 2011
No CASRN	n-Alkanes	Veil et al., 2004
124-18-5	n-Decane	Hum et al., 2006
3452-07-1	n-Eicosene	Hum et al., 2006
544-76-3	n-Hexadecane	Hum et al., 2006
593-45-3	n-Octadecane	Hum et al., 2006
629-59-4	n-Tetradecane	Hum et al., 2006
91-20-3	Naphthalene	Veil et al., 2004; OGP, 2002; OGP, 2005
7440-02-0	Nickel	Manfra et al., 2010; OGP, 2005
14797-55-8	Nitrate	Martel-Valles et al., 2013; OGP, 2005
14797-65-0	Nitrite	Martel-Valles et al., 2013
7727-37-9	Nitrogen	Guerra et al., 2011
7631-86-9	Non-crystalline silica [amorphous silica]	Hum et al., 2006
95-48-7	o-Cresol	Hum et al., 2006
59-50-7	p-Chloro-m-cresol	Veil et al., 2004
106-44-5	p-Cresol	Hum et al., 2006
85-01-8	Phenanthrene	Manfra et al., 2010; OGP, 2002; OGP, 2005
108-95-2	Phenol	Veil et al., 2004; OGP, 2005
7723-14-0	Phosphorous	Martel-Valles et al., 2013
No CASRN	Polyhydroxyalkanoates (PHA)	Hum et al., 2006
7440-09-7	Potassium	Martel-Valles et al., 2013
129-00-0	Pyrene	Manfra et al., 2010; OGP, 2002; OGP, 2005
7440-14-4	Radium 226	Veil et al., 2004; Neff, 2002
15262-20-1	Radium 228	Veil et al., 2004; Neff, 2002
7782-49-2	Selenium	Guerra et al., 2011
7440-22-4	Silver	Guerra et al., 2011
7440-23-5	Sodium	Guerra et al., 2011; Dorea et al., 2006
No CASRN	Steranes or cyclopentanoperhydrophenanthrene	Veil et al., 2004
7440-24-6	Strontium	Fillo et al., 1992; Dorea et al., 2006
No CASRN	Sulfate (SO ₄ ²⁻)	Veil et al., 2004; OGP, 2005; Dorea et al., 2006
7704-34-9	Sulfur	Martel-Valles et al., 2016
7440-31-5	Tin	Fillo et al., 1992
7440-32-6	Titanium	Guerra et al., 2011; OGP, 2002
108-88-3	Toluene	Manfra et al., 2010; OGP, 2005
No CASRN	Triterpenes	Veil et al., 2004
7440-61-1	Uranium	Guerra et al., 2011
7440-62-2	Vanadium	Guerra et al., 2011
1330-20-7	Xylene	Manfra et al., 2010; OGP, 2002; OGP, 2005
7440-66-6	Zinc	Guerra et al., 2011; OGP, 2005

REFERENCES FOR APPENDIX A

- Dórea, H.S., Bispo, J.R., Aragão, K.A., Cunha, B.B., Navickiene, S., Alves, J.P., Romão, L.P. and Garcia, C.A., 2007. Analysis of BTEX, PAHs and metals in the oilfield produced water in the State of Sergipe, Brazil. *Microchemical journal*, 85(2), pp.234-238.
- Fillo, J.P., Koraido, S.M. and Evans, J.M., 1992. Sources, characteristics, and management of produced waters from natural gas production and storage operations. In *Produced Water* (pp. 151-161). Springer, Boston, MA.
- Guerra, K., Dahm, K. and Dundorf, S., 2011. Oil and gas produced water management and beneficial use in the Western United States. US Department of the Interior, Bureau of Reclamation. <https://www.usbr.gov/research/dwpr/reportpdfs/report157.pdf>
- Hum F., Tsang P., Harding T. and Kantzas A. 2006. Re- view of produced water recycle and beneficial reuse. Paper No. 19 of the Alberta Energy Futures Project. The Institute for Sustainable Energy, Environment and Economy. Calgary, Canada, 51 pp.
- Liske R. A. and Leong L. Y. C. (2006). Beneficial reuse of San Ardo produced water. Final report. <http://www.osti.gov/scitech/servlets/purl/898785> 19/02/16.
- Manfra, L., Maggi, C., Bianchi, J., Mannozi, M., Faraponova, O., Mariani, L., Onorati, F., Tornambè, A., Lamberti, C.V. and Magaletti, E., 2010. Toxicity evaluation of produced formation waters after filtration treatment. *Natural Science*, 2(01), p.33.
- Martel-Valles, J.F., Benavides-Mendoza, A., Valdez-Aguilar, L.A., Juárez-Maldonado, A. and Ruiz-Torres, N.A., 2013. Effect of the application of produced water on the growth, the concentration of minerals and toxic compounds in tomato under greenhouse. *Journal of environmental protection*, 4(07), p.138.
- Martel-Valles, J.F., Foroughbakchik-Pournavab, R. and Benavides-Mendoza, A., 2016. Produced waters of the oil industry as an alternative water source for food production. *Revista Internacional de Contaminación Ambiental*, 32(4), pp.463-475.
- Neff, J M. 2002. Bioaccumulation in marine organisms. Effect of contaminants from oil well produced water. Elsevier, London. 2002.
- OGP. 2002. Aromatics in produced water: occurrence, fate & effects, and treatment. International Association of Oil & Gas Producers. Report No. I.20/324 January 2002.
- OGP. 2005. Fate & effects of naturally occurring substances in produced water on the marine environment. International Association of Oil & Gas Producers. Report No. 364. February 2005.
- Veil, J.A., Puder, M.G., Elcock, D. and Redweik Jr, R.J., 2004. A white paper describing produced water from production of crude oil, natural gas, and coal bed methane (No. ANL/EA/RP-112631). Argonne National Lab., IL (US).

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APPENDIX B: LIST OF CHEMICAL ADDITIVES EVALUATED FOR TOXICITY

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Appendix Table B: List of chemical additives evaluated for toxicity

CASRN	Chemical Name
629-73-2	1-Hexadecene
2634-33-5	1,2 Benzisothiazol-3(2H)-one
526-73-8	1,2,3-Trimethylbenzene
95-63-6	1,2,4-Trimethylbenzene
108-67-8	1,3,5-Trimethylbenzene
123-91-1	1,4 Dioxane
479-66-3	1H, 3H-Pyrano (4,3-b)(1)benzopyran-9-carboxylic acid, 4,10-dihydro-3,7,8 trihydroxy-3-methyl-10-oxo
124-68-5	2-Amino-2-methylpropanol
111-76-2	2-Butoxyethanol
104-76-7	2-Ethylhexan-1-ol
115-19-5	2-methyl-3-Butyn-2-ol
27646-80-6	2-Methylamino-2-methyl-1-propanol
67990-40-3	2-Propen-1-aminium, N,N-dimethyl-N-2-propenyl-, chloride, polymer with 2-hydroxypropyl 2-propenoate and 2-propenoic acid
145417-45-4	2-Propenoic acid, 2-methyl-, polymer with methyl 2-methyl-2-propenoate, octadecyl 2-methyl 2 propenoate and 2propenoic acid, sodium salt
9033-79-8	2-propenoic acid, polymer with sodium 2-propenoate
130800-24-7	2-Propenoic acid, telomer with 2-methyl-2-(1-oxo-2-propenyl)-1-propanesulfonic acid, sodium salt
75-07-0	Acetaldehyde
64-19-7	Acetic acid
67-64-1	Acetone
107-02-8	Acrolein
100-73-2	Acrolein dimer
79-06-1	Acrylamide
79-10-7	Acrylic Acid
No CASRN	Alcohols, C-10-14 ethoxylated
68551-12-2	Alcohols, C12-16, ethoxylated
68951-67-7	Alcohols, C14-C15, ethoxylated
No CASRN	Alcohols, C9-11, ethoxylated
90622-58-5	Alkanes, C11-15-iso
90622-46-1	Alkanes, C14-16
29868-05-1	Alkanolamine phosphate
68439-70-3	Alkyl amine
68081-81-2	Alkyl benzenesulfonate
68424-85-1	Alkyl dimethylbenzyl ammonium chloride
68910-32-7	Alkylaryl sulfonates
90218-35-2	Alkylarylsulfonate amine salt

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Appendix Table B continued... List of chemical additives evaluated for toxicity

CASRN	Chemical Name
90320-37-9	Almond Shell
1344-28-1	Aluminium oxide
7446-70-0	Aluminum chloride
1327-41-9	Aluminum chlorohydrate
300-92-5	Aluminum distearate
No CASRN	Amide surfactant acid salt
No CASRN	Amides, Non Ionics
61791-24-0	Amine derivative
67924-33-8	Amine salt
NP-U2856	Amine salt
64346-44-7	Amine sulfate
926-39-6	Amine sulfate [Ethanolamine-O-sulfate]
68910-31-6	Ammonium alkylaryl sulfonates
1863-63-4	Ammonium benzoate
1341-49-7	Ammonium bifluoride
10192-30-0	Ammonium bisulfate
12125-02-9	Ammonium Chloride
7783-20-2	Ammonium sulfate
1309-64-4	Antimony trioxide
No CASRN	Aromatic Amine
7727-43-7	Barite
7440-39-3	Barium
1302-78-9	Bentonite
71-43-2	Benzene
68648-87-3	Benzene, c10-c16 alkyl derivatives
25265-78-5	Benzene, tetrapropylene-
68584-22-5	Benzenesulfonic acid, C10-16-alkyl derivs
68584-27-0	Benzenesulfonic acid, C10-16-alkyl derivs., potassium salts
65-85-0	Benzoic acid
100-44-7	Benzyl chloride
27176-87-0	Branched DDBSA
68551-19-9	C12-C14 Isoalkanes
68551-20-2	C12-C14 Isoalkanes
68855-24-3	C14-30 Alkyl Derivatives [Benzenesulfonic acid, mono-C10-16-alkyl derivs., ammonium salts]
7440-43-9	Cadmium
471-34-1	Calcium carbonate
1305-78-8	Calcium Oxide
7778-18-9	Calcium sulfate
7440-44-0	Carbon

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CASRN	Chemical Name
69418-26-4	Cationic acrylamide copolymer
44992-01-0	Cationic acrylamide monomer
54076-97-0	Cationic polymer
681331-04-4	Causticized Lignite
No CASRN	Cedar fiber
9005-81-6	Cellophane
9004-34-6	Cellulose, microcrystalline
7440-47-3	Chromium
77-92-9	Citric acid
61791-31-9	Cocamide DEA
64743-05-1	Coke (petroleum), calcined
25987-30-8	Copolymer of acrylamide and sodium acrylate
7440-50-8	Copper
7758-99-8	Copper sulfate pentahydrate
68308-87-2	Cottonseed, flour
129828-31-5	Crosslinked polyol ester
14464-46-1	Crystalline silica (cristobalite)
14808-60-7	Crystalline silica (quartz)
14808-60-7	Crystalline silica (quartz)
15468-32-3	Crystalline silica (tridymite)
15468-32-3	Crystalline silica (tridymite)
98-82-8	Cumene
108-93-0	Cyclohexanol
108-91-8	Cyclohexylamine
25155-15-1	Cymenes
5989-27-5	d-Limonene
2673-22-5	Diester of sulfosuccinic acid sodium salt
111-42-2	Diethanolamine
63148-62-9	Dimethyl siloxanes and silicones
577-11-7	Dioctyl sulfosuccinate sodium salt
10042-91-8	Diphosphoric acid, sodium salt
34590-94-8	Dipropylene glycol monomethyl ether
38011-25-5	Disodium ethylenediaminetetraacetate
7758-16-9	Disodium pyrophosphate
64742-53-6	Distillates, hydrotreated light naphthenic
125005-87-0	Diutan
112-40-3	Dodecane
143-07-7	Dodecanoic acid

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CASRN	Chemical Name
No CASRN	Drilling paper
64-17-5	Ethanol
126-97-6	Ethanolamine thioglycolate
78330-21-9	Ethoxylated alcohol C11-14
68439-45-2	Ethoxylated alcohol C6-12
61791-26-2	Ethoxylated amine
No CASRN	Ethoxylated C11 Alcohol
9081-83-8	Ethoxylated octylphenol
141-78-6	Ethyl acetate
140-88-5	Ethyl acrylate
5877-42-9	Ethyl octynol
100-41-4	Ethylbenzene
107-21-1	Ethylene glycol
84012-43-1	Extract of walnut
67762-38-3	Fatty acid ester
61790-12-3	Fatty acids, tall-oil
61790-45-2	Fatty acids, tall-oil, sodium salts
61788-91-8	Fatty alkyl amines
17375-41-6	Ferrous sulfate, monohydrate
50-00-0	Formaldehyde
63428-92-2	Formaldehyde, polymer with 2-methyloxirane, 4-nonylphenol and oxirane
30704-64-4	Formaldehyde, polymer with 4-(1,1-dimethylethyl)phenol, 2-methyloxirane and oxirane
30846-35-6	Formaldehyde, polymer with 4-nonylphenol and oxirane
75-12-7	Formamide
98-00-0	Furfuryl alcohol
111-30-8	Glutaraldehyde
97722-02-6	Glycerides, tall oil mono-, di, and tri
56-81-5	Glycerol
79-14-1	Glycolic acid
107-22-2	Glyoxal
7782-42-5	Graphite
64742-94-5	Heavy aromatic naphtha
No CASRN	Heavy catalytic reformed naptha
1415-93-6	Humic acids
7647-01-0	Hydrochloric Acid
7664-39-3	Hydrofluoric acid
7722-84-1	Hydrogen peroxide
123-31-9	Hydroquinone

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CASRN	Chemical Name
64742-47-8	Hydrotreated Light Petroleum Distillate
9004-62-0	Hydroxyethyl cellulose
2809-21-4	Hydroxyethylidenediphosphonic acid
7783-18-8	Inorganic sulfur compound [Ammonium thiosulfate]
7553-56-2	Iodine
No CASRN	Ionic Surfactants
67-63-0	Isopropanol
119-65-3	Isoquinoline
8008-20-6	Kerosene
7439-90-9	Krypton
7439-92-1	Lead
64741-46-4	Light aliphatic naphtha
129521-66-0	Lignite
1317-65-3	Limestone
554-13-2	Lithium carbonate
13453-71-9	Lithium chlorate
7447-41-8	Lithium chloride
1310-65-2	Lithium hydroxide
13840-33-0	Lithium hypochlorite
No CASRN	Magma fiber
7439-97-6	Mercury
67-56-1	Methanol
74-87-3	Methyl Chloride
No CASRN	Methyl ester of sulfonated tannin
PE-M2464	Methyl oxirane polymer
26172-55-4	Methylchloroisothiazolinone
8012-95-1	Mineral Oil
141-43-5	Monoethanolamine
1302-93-8	Mullite
91-20-3	Naphthalene
7440-02-0	Nickel
7786-81-4	Nickel sulfate
6419-19-8	Nitrilotris (methylene phosphonic acid)
7631-86-9	Non-crystalline silica [amorphous silica]
No CASRN	Nonylphenol ethoxylates
127087-87-0	Nonylphenol polyethylene glycol ether
No CASRN	Nutshell
112-80-1	Oleic acid

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CASRN	Chemical Name
8028-48-6	Orange terpenes
No CASRN	Organic acid ethoxylated alcohols
68412-54-4	Oxyalkylated alkylphenol
68171-44-8	Oxyalkylated alkylphenolic resin
67939-72-4	Oxyalkylated polyamine
68910-19-0	Oxyalkylated polyamine
64742-55-8	Paraffinic petroleum distillate, hydrotreated light
56919-55-2	Pentadecane, 3-methylene
115146-98-0	Pentadecane, 5-methylene
13043-55-5	Pentadecane, 7-methylene
140-01-2	Pentasodium diethylenetriamine pentaacetate
79-21-0	Peracetic acid
68123-18-2	Phenol, 4,4'-(1-methylethylidene) bis-, polymer with 2-(chloromethyl)oxirane, 2-methyloxirane and oxirane
68425-75-2	Phosphate ester salt
13397-24-5	Phosphogypsum [Gypsum]
13598-36-2	Phosphonic acid
55566-30-8	Phosphonium, tetrakis (hydroxymethyl)- sulfate (2:1) salt
7664-38-2	Phosphoric acid
8002-09-3	Pine oil
110-85-0	Piperazine
9005-70-3	POE (20) Sorbitan Trioleate
69011-36-5	Poly(oxy-1,2-ethanediyl), a-tridecyl-w-hydroxy-branched
9003-05-8	Polyacrylamide
9003-79-8	Polyacrylate
9003-01-4	Polyacrylic acid
26100-51-6	Polyactide resin [Polylactic acid]
68955-69-1	Polyamine salts
19019-43-3	Polycarboxlate salt [Trisodium ethylenediaminetetraacetate]
26062-79-3	Polydimethyl diallyl ammonium chloride
No CASRN	Polydimethylsiloxane emulsion
74-84-0	Polyethylene
74-84-0	Polyethylene [Ethane]
25322-68-3	Polyethylene oxide
25038-59-9	Polyethylene terephthalate
68036-92-0	Polyglycol diepoxide
68036-95-3	Polyglycol diepoxide
9038-95-3	Polyglycol ether
64741-71-5	Polymers (petroleum) viscous

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CASRN	Chemical Name
36484-54-5	Polyoxyalkylene glycol
61790-86-1	Polyoxyalkylenes
9014-93-1	Polyoxyethylene dinonylphenol
12068-19-8	Polyoxyethylene nonyl phenyl ether phosphate
70142-34-6	Polyoxyl 15 hydroxystearate
25322-69-4	Polypropylene glycol
42751-79-1	Polyquaternary amine
9002-89-5	Polyvinyl alcohol
127-08-2	Potassium acetate
7646-93-7	Potassium bisulfate
7447-40-7	Potassium chloride
1310-58-3	Potassium hydroxide
12136-45-7	Potassium oxide
107-19-7	Propargyl alcohol
123-38-6	Propionaldehyde
57-55-6	Propylene glycol
61790-41-8	Quaternary ammonium compound
68609-18-7	Quaternized condensed alkanolamines
91-63-4	Quinaldine
68153-60-6	Salt of fatty acid polyamine
1319-41-1	Saponite
No CASRN	Severely hydrotreated paraffinic
1318-93-0	Smectite
127-09-3	Sodium acetate
532-32-1	Sodium benzoate
144-55-8	Sodium bicarbonate
7631-90-5	Sodium bisulfite
68439-57-6	Sodium C14-16 olefin sulfonate
497-19-8	Sodium carbonate
9063-38-1	Sodium carboxymethyl starch
9004-32-4	Sodium carboxymethylcellulose
7775-09-9	Sodium chlorate
7647-14-5	Sodium chloride
2893-78-9	Sodium dichloroisocyanurate
6381-77-7	Sodium erythorbate
2836-32-0	Sodium glycolate
7681-52-9	Sodium Hypochlorite
7681-82-5	Sodium iodide

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CASRN	Chemical Name
1313-59-3	Sodium oxide
9003-04-7	Sodium polyacrylate
7757-82-6	Sodium sulfate
12179-04-3	Sodium tetraborate pentahydrate
7772-98-7	Sodium thiosulfate
10102-17-7	Sodium thiosulfate pentahydrate
7785-84-4	Sodium trimetaphosphate
No CASRN	Solvent dewaxed heavy paraffinic
64742-95-6	Solvent naphtha, petroleum, light arom.
NP-SMO3_U1240	Sorbitan ester
9005-65-6	Sorbitan monooleate, ethoxylated
1338-43-8	Sorbitan, mono-(9Z)-9-octadecenoate [Sorbitan oleate]
67784-80-9	Soybean oil, Me ester
57-11-4	Stearic acid
65996-69-2	Steel mill slag
8052-41-3	Stoddard Solvents
7446-09-5	Sulfur dioxide
61790-33-8	Tallow alkyl amines
72480-70-7	Tar bases, quinoline derivatives, quaternized benzyl chloride
629-59-4	Tetradecane
25265-78-5	Tetrapropylenebenzene (1-phenyldodecane)
64-02-8	Tetrasodium ethylenediaminetetraacetate
68527-49-1	Thiourea, polymer with formaldehyde and 1-phenylethanone
13463-67-7	Titanium dioxide
108-88-3	Toluene
4719-04-4	Triazinetriethanol
629-50-5	Tridecane
64114-46-1	Triethanolamine homopolymer
112-27-6	Triethylene Glycol
13573-18-7	Triphosphoric acid, sodium salt
5064-31-3	Trisodium nitrilotriacetate
1120-21-4	Undecane
57-13-6	Urea
7732-18-5	Water
No CASRN	Wood dust
11138-66-2	Xanthan gum
7440-63-3	Xenon
1330-20-7	Xylene

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CASRN	Chemical Name
7440-66-6	Zinc
7646-85-7	Zinc chloride

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